EMPIRE MINING AND METALLURGICAL CONGRESS
CANADA
1927

PROCEEDINGS

PART V. NON-FERROUS

TN
5
.E6
1927
pt.5

NUNC COGNOSCO EX PARTE

THOMAS J. BATA LIBRARY
TRENT UNIVERSITY

Digitized by the Internet Archive
in 2019 with funding from
Kahle/Austin Foundation

https://archive.org/details/proceedings0000empi_b8z1

Second (*Triennial*)
Empire Mining and Metallurgical Congress

PROCEEDINGS

PART V.

NON-FERROUS METALLURGY

(SECTION D OF CONGRESS)

PROCEEDINGS OF THE SECOND (TRIENNIAL) *EMPIRE MINING AND METALLURGICAL CONGRESS, CANADA, 1927.*

Part I.—Report of Proceedings, Inaugural and other Addresses, and General Papers.

Part II.—Mining.

Part III.—Petroleum.

Part IV.—Iron and Steel.

Part V.—Non-Ferrous Metallurgy.

The price of these Proceedings is $10.00 for the whole of the five parts, or any part may be obtained separately for $3.00.

Second (*Triennial*)

Empire Mining and Metallurgical Congress

Held in Canada, August 22nd to September 28th, 1927.

PROCEEDINGS

Edited by

R. P. D. GRAHAM

PART V

NON-FERROUS METALLURGY

(SECTION D OF CONGRESS)

MONTREAL, CANADA:
PUBLISHED AT THE OFFICES OF THE CONGRESS
923 DRUMMOND BUILDING, MONTREAL.
1928

TN5 .E6 1927 pt.2

Second (*Triennial*)
Empire Mining and Metallurgical Congress

Canada, August 22nd to September 28th, 1927

Convening Body

The Canadian Institute of Mining and Metallurgy.

HONORARY PRESIDENT

RT. HON. SIR ROBERT S. HORNE, G.B.E., K.C., M.P.

President

Hon. Charles Stewart, M.P., *Minister of Mines for Canada.*

Honorary Vice-Presidents

The Secretary of State For Dominion Affairs

The Secretary of State For India

The Secretary of Mines For Great Britain

The Prime Ministers of:

Australia, Canada, Great Britain, New Zealand, Newfoundland, South Africa

The Premiers and Ministers of Mines of:

Alberta, British Columbia, Manitoba, New Brunswick, Nova Scotia,
Ontario, Quebec, Saskatchewan

Vice-Presidents

The Presidents of The Ten Constituent Institutions

Charles Camsell, LL.D., F.R.S.C., F.G.S.A., *Deputy Minister of Mines for Canada*

Chairman of the Main Committee	George C. Riley
Vice-Chairman of the Main Committee	J. G. Ross
Chairman of the Finance Committee	J. L. Agnew
Chairman of the Transportation Committee	Guy Tombs
Chairman of the Reception Committee	J. Mackintosh Bell
Chairman of the Publications Committee	W. H. Collins
Honorary Treasurer	Sir Charles Gordon
Treasurer	Winthrop Brainerd
General Secretary	G. C. Mackenzie
Associate Secretary	R. O. Wheatley
Editor	R. P. D. Graham

Canadian Main Committee

J. L. Agnew
C. A. Banks
J. P. Bickell
A. F. Brigham
R. A. Bryce
C. V. Corless
J. A. Dresser
N. R. Fisher
A. M. Irvine
D. H. Macdougall
Lewis Stockett
R. C. Wallace
J. J. Warren
F. R. Weekes

Second (*Triennial*)
Empire Mining and Metallurgical Congress

PREFACE

The conditions under which the Second Congress was held were different in several notable respects from those of the First Congress, which met in London in June, 1924. That meeting, convened by institutions and associations representing the mineral and metal industries, the colliery proprietors, and the iron and steel manufacturers, in the United Kingdom, lasted only four days, and the sessions were all held at the British Empire Exhibition, Wembley. It was, of necessity, inaugural in character, and apart from the presentation of a series of noteworthy papers dealing with various phases of the mining and metallurgical industries of the Empire, it had as its chief business the drafting and adoption of a Constitution and Rules for an Empire Council of Mining and Metallurgical Institutions. The Constitution as adopted is as follows:

CONSTITUTION

The Council shall consist, until otherwise determined, of two representatives from each of the following Constituent Institutions:

The Institution of Mining and Metallurgy
The Institution of Mining Engineers
The Institution of Petroleum Technologists
The Canadian Institute of Mining and Metallurgy
The Australasian Institute of Mining and Metallurgy
The Chemical, Metallurgical and Mining Society of South Africa
The South African Institution of Engineers
The Mining and Geological Institute of India
The Iron and Steel Institute
The Institute of Metals

OBJECTS OF THE COUNCIL

To serve as an organ of intercommunication and co-operation between the Constituent Bodies and for the promotion and protection of their common interests.

FUNCTIONS OF THE COUNCIL

(*a*) To foster and maintain throughout the Empire a high level of technical efficiency and professional status.

(*b*) To convene successive Mining and Metallurgical Congresses within the Empire.

POWERS OF THE COUNCIL

> The Council shall have power to initiate projects for consideration with a view to action and generally to direct the affairs committed to it by the Constituent Institutions, but it shall not commit them to any act or financial obligation without first obtaining the sanction of the respective Councils. Further, the Council shall not have any authority, implied or explicit, to interfere in the domestic affairs of any of the Constituent Institutions, whose complete autonomy shall remain intact.

Dr. R. C. Wallace, as President of the Canadian Institute of Mining and Metallurgy at that time, was one of the official delegates of the Canadian Institute attending the First Empire Congress in London, and on his return to Canada he submitted a proposal to the Institute Council that they should consider the feasibility of having the Second Congress meet in Canada. The proposal was received with enthusiasm, and a preliminary canvass of the situation having made it evident that the Institute might safely assume the responsibility of acting as convenor, an invitation was forwarded to the Empire Council to hold the Second Congress in Canada in 1927. This invitation was accepted by the Empire Council on behalf of the Constituent Institutions.

The Second Congress opened in Montreal on August 22nd, with addresses by the Honorary President, The Right Hon. Sir Robert S. Horne, *G.B.E.*, *K.C.*, *M.P.*, and the President, the Hon. Charles Stewart, *M.P.*, Minister of Mines for Canada. Technical sessions were held on this and the following day, the proceedings including the presentation of a notable paper by Sir Thomas H. Holland on a *Proposed Review of the Mineral Resources of the Empire.* The proposals outlined in this paper were warmly endorsed in addresses by official representatives from various parts of the Empire, and at the conclusion of the discussion the following resolution was adopted:

> This Second (Triennial) Empire Mining and Metallurgical Congress, assembled in Canada, having discussed a proposal for instituting a review of the mineral resources and industries in each appropriate administrative unit throughout the Empire, and of the conditions affecting their development, embodied in a paper submitted under the auspices of The Institution of Mining and Metallurgy by Sir Thomas H. Holland,
>
> RESOLVED, that the proposal be referred to the Empire Council of Mining and Metallurgical Institutions, to be transmitted to the Councils of the constituent bodies for consideration, with a request that they will formulate their views and communicate them to the Empire Council for further action.

On the following day, special trains conveyed the party to Ottawa, where members had the opportunity of meeting His Excellency the Viscount Willingdon, Governor General of Canada, and The Hon. Charles Stewart, representing the Prime Minister, at a luncheon tendered by the Congress.

Following this, two days were devoted to technical sessions in Toronto, and over the week-end there were excursions to Hamilton, Niagara Falls, and other points of interest.

From Toronto, the Congress trains proceeded to some of Ontario's world-famous mining districts, visits being paid in turn to nickel-copper mines at Sudbury, silver mines at Cobalt, and gold mines at Kirkland Lake and Porcupine.

After leaving the Porcupine area, the party divided, those who had elected to take Tour *A* going westward to the Pacific coast, while Tour *B* proceeded eastward across Quebec and the Maritime Provinces to Newfoundland. In each case the principal mining centres and metallurgical plants, as well as some hydro-electric plants, were visited, and a number of technical sessions were held: on Tour *A*, in Winnipeg, Vancouver, Jasper, and Quebec; and on Tour *B* in Quebec and St. John's, Newfoundland. Tour *A* covered approximately 7,750 miles, and Tour *B* 5,525 miles. The final session of the Congress was held in Quebec on September 26th. It is with considerable gratification that we are able to record that, from the opening day to the closing of the Congress, there was not a single case of illness nor an accident of any kind.

Official banquets were held in Montreal, Toronto, Winnipeg, Vancouver, and Jasper, and in St. John's, Newfoundland. At numerous other points the Congress parties were lavishly entertained by mining companies and individuals; and golf and other clubs in the various cities visited were most hospitable in extending facilities for recreation. The Congress is especially indebted to the Ladies' Committees, which, at each stopping place in the course of the tours, were indefatigable in providing entertainment for the visiting ladies.

Lists compiled from the official registers and other available sources show that the total attendance at the Congress was well over twelve hundred. Of these, 350 participated in

Tour *A* and 96 in Tour *B*. The gathering may be truly described as exceptionally well representative of every important phase of the mining and metallurgical industries in all parts of the Empire. The personnel included official delegates from each of the following institutions:

The Institute of Metals (London)
The Institution of Mining Engineers (London)
The Institution of Mining and Metallurgy (London)
The Iron and Steel Institute (London)
The Institution of Petroleum Technologists (London)
The Chemical, Metallurgical, and Mining Society of South Africa
The South African Institution of Engineers
The Rhodesia Chamber of Mines
The Australasian Institute of Mining and Metallurgy
The Mining and Geological Institute of India
The Canadian Institute of Mining and Metallurgy

In addition, the Congress had the privilege of welcoming official delegates from the United States Bureau of Mines and the American Institute of Mining and Metallurgical Engineers.

A total of 42 papers were presented at the several technical sessions, and with the exception of three these were all printed as 'separates' in advance of the opening of the Congress and distributed to delegates before the meetings. In addition, a 270-page Official Programme was issued giving complete information regarding arrangements for the Congress, with itineraries of the excursions and brief descriptions of the various points of interest visited; and a series of 'short focus' papers was prepared, each giving in concise form particulars of operations at individual mines and metallurgical plants inspected during the tours. Besides these purely Congress publications, specially prepared booklets descriptive of the Dominion's mining and metallurgical industries were issued by the Federal Department of Mines, by the Ontario and Quebec departments of mines, and by several of the mining companies.

The papers submitted to the Congress dealt with a wide variety of topics relating to recent progress, and the present status and future prospects, of the mining and metallurgical industries in almost every section of the Empire where these industries are carried on. Many of the papers have been given wider publicity than was possible at the time of the

Congress by publication in the *Transactions* of the constituent institutions, and some also in technical journals. Following the procedure of the First Congress, the complete *Proceedings* are now issued in five Volumes, a full list of the Papers being printed in each volume.

The funds required for carrying out the extensive programme of the Congress were in the main contributed by the Dominion Government, by the governments of the several Provinces, by the Government of Newfoundland, by Canadian mining and smelting companies, and manufacturers of mining machinery, explosives, etc., and by the Canadian Pacific and the Canadian National railways. Generous donations were also received from co-operating Institutions in the United Kingdom, South Africa, Australasia, and India. In all, sixty-six contributions were received, totalling about $110,000.

The Second Congress was exceedingly fortunate in having, as its Honorary President, the Right Hon. Sir Robert S. Horne, *G.B.E.*, *K.C.*, *M.P.*, who took a most active interest in the proceedings and participated in the Montreal meeting. Much of the success of the Congress was due also to the President, The Hon. Charles Stewart, Minister of Mines for Canada, who rendered great services, both personally and through the Department of Mines, technical officers of which were detailed to accompany each of the special trains, and were available at all times to give information regarding the Dominion's mineral resources and industries. The Congress also received whole-hearted support from the departments of mines of each of the Provinces of Canada, and from the Government of Newfoundland.

Mining companies throughout Canada, and also the two great transcontinental railway systems, the Canadian Pacific and the Canadian National, and the Temiskaming and Northern Ontario railway, took a very active interest in the work of the organization and showed a keen appreciation of its importance to the Empire. The Congress owes much to them for their invaluable co-operation, and also to the management of the various mines and plants visited for their unfailing readiness to do all in their power to make the tours both instructive and enjoyable.

Acknowledgment must also be made of the notable service rendered by the numerous individuals who composed the various committees responsible for the organization and carrying out of the Congress. The smoothness with which the entire Congress programme functioned is a splendid tribute to the efficient manner in which each of these committees carried out the particular duties assigned to it.

We desire further to record our thanks to the Empire Council of Mining and Metallurgical Institutions, and more especially to its joint general secretaries, Mr. Charles McDermid and Mr. George C. Lloyd, for much helpful advice both during the organization period and while the Congress was in progress. Thanks are also due to the Cunard Steamship Company for the excellent arrangements they made for the comfort of delegates who sailed from England to Canada in the official Congress boat, the *Alaunia*.

Although the Empire Council Banquet, held in London on November 22nd, was an aftermath, and not a part of the actual proceedings, of the Congress, it may be fittingly referred to here since a large proportion of those present had been with the Congress in Canada, and one of its objects was to review the results of the Congress. Notable speeches were delivered by Sir Thomas H. Holland, Chairman of the Empire Council, who presided, and by others prominently identified with the mining and metallurgical industries, as well as by representatives of the governments of various parts of the Empire.

GEO. C. MACKENZIE,
General Secretary.

R. O. WHEATLEY,
Associate Secretary.

923 Drummond Building,
Montreal,
April, 1928.

TABLE OF CONTENTS, PARTS I-V

PART I

(General Section of Congress)

REPORT OF PROCEEDINGS

Addresses at Inaugural Session, Montreal:

The Mineral Industries of the Empire: By the Hon. President, The Right Hon. Sir Robert Horne, *G.B.E., K.C., M.P.*

The Status of the Canadian Mineral Industry: By the President, The Hon. Charles Stewart, *Minister of Mines for Canada.*

Technical Sessions, Receptions, etc. at Montreal, Ottawa, Toronto, Niagara Falls, and Hamilton.

The Trans-Canada Tours *A* **and** *B* **(including Newfoundland):** Itinerary, Technical Sessions, Receptions, etc.

Concluding General Session at Quebec.

PAPERS

'Proposed Review of the Mineral Resources of the Empire': By Sir Thomas H. Holland (President, The Institution of Mining and Metallurgy) and Other Authors.
Discussion.
Adoption of resolution.

'An Outline of Mining and Metallurgical Practice in Australasia':
Vol. I, By Leading Authorities in Collaboration.
(*Prepared by request of the Australasian Institute of Mining and Metallurgy*).
Vol. II, **'The Utilization of Brown Coal in Victoria':** By H. Herman (Member, Aust. Inst. M. & M.)

'Base Metal and Base Mineral Resources of The Union of South Africa': By C. J. N. Jourdan (Member, C.M. & M. Soc. S. Af.)
Discussion.

'The Development of Gold Mining in Canada': By Geo. E. Cole (Member, C. Inst. M. & M.)
Discussion.

'The Silver Mining Industry in Canada': By Arthur A. Cole (Member, C. Inst. M. & M.)
Discussion.

'Canadian Copper and its Production': By C. P. Browning (Member, C. Inst. M. & M.)
Discussion.

'Lead and Zinc in Canada': By T. W. Bingay and F. J. Alcock (Members, C. Inst. M. & M.)
Discussion.

'Portland Cement in Canada': By W. A. Toohey.

'Mineral Exploration in Newfoundland During the Past Decade': By A. K. Snelgrove (Student Member, C. Inst. M. & M.)

'The St. George's Coal Field, Newfoundland': By Herbert A. Baker.

PART II—MINING

(Section A of Congress)

'Mining Coal under the Sea in Nova Scotia': By F. W. Gray (Member, C. Inst. M. & M.)
Discussion.

'The Coal Mining Industry of Western Canada': By R. Strachan, W. J. Dick, and R. J. Lee (Members, C. Inst. M. & M.)
Discussion.

'Coal Washing at the Linsi Mine, Kailan Mining Administration, North China': By Alex. Docquier, L. Bataille, and R. Beetlestone. (Communicated by W. S. Nathan, Member, Inst. M. & M.)

'Progress in Research on Health and Safety in Coal Mining, 1924-27': By J. S. Haldane (Hon. Member, Inst. M.E.) and R. V. Wheeler (Member, Inst. M.E.)

'Asbestos Mining and Milling': By J. G. Ross (Member, C. Inst. M. & M.)

'Dewatering the Lower Levels of the Simmer and Jack Mines, Limited': By R. Craib (Member, S.Af. Inst. Eng.)
Discussion.

'The Tipping and Guiding of Vertical Skips': By G. W. Sharp (Member, S.Af. Inst. Eng.)

'Deep Level Mining and High Temperatures': By A. Mavrogordato and H. Pirow (Members, S.Af. Inst. Eng.)
Discussion.

'The Sinking and Equipment of the Ventilation Shaft of the Government Gold Mining Areas Mine': By A. Job (Member, S.Af. Inst. Eng.)
Discussion.

'Improvements in Drilling Efficiency with Jack-Hammers': By P. M. Newhall and L. Pryce (Members, S.Af. Inst. Eng.)
Discussion.

'A New Form of Air Meter and the Measurement of Compressed Air': By E. J. Laschinger (Member, S.Af. Inst. Eng.)
Discussion.

'Methods of Eliminating Barren Rock from Ore at The Sub Nigel Mine, Transvaal': By W. A. Quince (Member, C. M. & M. Soc. S. Af.)
Discussion.

'Method of Mining at Wabana': By J. B. Gilliatt.

PART III—PETROLEUM

(*Section B of Congress*)

‘Conditions affecting the Petroleum Prospects of the Empire’: By Sir Thomas H. Holland (Member, Inst. P.T.)

‘Economics of the Petroleum Situation in British Dominions’: By Sir Frederick Black (Member, Inst. P.T.)

‘Progress and Prospects of Oil Production’: By E. H. Cunningham-Craig (Member, Inst. P.T.)

‘Petroleum Refining Facilities within the British Empire’: By James McConnell Sanders (Member, Inst. P.T.)

‘Petroleum and Natural Gas in the Dominion of Canada’: By R. B. Harkness, G. S. Hume, O. B. Hopkins, S. C. Ells, R. T. Elworthy, and S. J. Cook, with an introduction by John Ness (Members, C. Inst. M. & M.)
Discussion.

‘Possible Auxiliary Sources of Liquid Fuels’: By A. W. Nash (Member, Inst. P.T.)
Discussion.

PART IV—IRON AND STEEL

(*Section C of Congress*)

‘Manganese, the Ores and the Metal; with an Account of the History and Production of Ferro-Manganese’: By Sir Robert A. Hadfield, Bt. (Member, I. & S. Inst.)

‘Low-Carbon Alloys of Iron and Manganese’: By Sir Robert A. Hadfield, Bt. (Member, I. & S. Inst.)

‘India’s Resources in Raw Materials for a Domestic Iron and Steel Industry’: By Cyril S. Fox (Member, M. & G. Inst. of India.)

‘The Manufacture of Steel in India by the Duplex Process’: By B. Yaneske (Member, I. & S. Inst.)

‘Magnesia Refractories for Steel Furnaces’: By G. M. Carrie (Member, C. Inst. M. & M.) and C. F. Pascoe.

‘The Cascade Method of Pouring Steel’: By J. G. Morrow (Member, C. Inst. M. & M.)

‘The Impact Resistance of Steels at Low Temperatures’: By I. F. Morrison and A. E. Cameron (Member, C. Inst. M. & M.)

‘Smelting Titaniferous Ores of Iron’: By A. Stansfield (Member, C. Inst. M. & M.)
Discussion.

PART V—NON-FERROUS METALLURGY

(Section D of Congress)

'Nickel—Past and Present': By ROBERT C. STANLEY (Member, Am. Inst. M. & M. E.)

'Precious Metals in the Sudbury Ores and their Recovery': By C. LANGER and C. JOHNSON (Members, Inst. of Metals.)
Discussion.

'Notes on the Operation of the Reduction Plant at West Springs, Limited': By CARL R. DAVIS, J. L. WILLEY, and S. E. T. EWING (Members, S. Af. Inst. Eng.)

'The Contact Process for the Manufacture of Sulphuric Acid from Zinc Blende Roaster Gases': By STANLEY ROBSON (Member, Inst. of Metals.)
Discussion.

PART V—NON-FERROUS METALLURGY

(*Section D of Congress*)

CONTENTS

PAGE

Preface v

Table of Contents of Parts I—V xi

Papers and Discussion

'Nickel—Past and Present': By ROBERT C. STANLEY . . 1

'Precious Metals in the Sudbury Ores and their Recovery': By C. LANGER, SR., and C. JOHNSON (*Members, Inst. of Metals*) 35

Discussion 41

'Notes on the Operation of the Reduction Plant at West Springs, Ltd.': By CARL R. DAVIS, J. L. WILLEY, and S. E. T. EWING (*Members, S. Af. Inst. Eng.*) . . 47

'The Contact Process for the Manufacture of Sulphuric Acid from Zinc Blende Roaster Gases': By STANLEY ROBSON (*Member, Inst. Met.*) 64

Discussion 95

Personal Index 101

General Index 103

NICKEL—PAST AND PRESENT

BY ROBERT C. STANLEY*

(Toronto, Ont., Meeting, August 25th, 1927)

The prominence of her mineral resources makes Canada a most fitting place in which to hold the Second Empire Mining and Metallurgical Congress, since in all probability the Dominion has more diversified mineral wealth than any other part of the British Empire.

This paper is concerned with nickel, an important factor of Canada's mineral production. The richness and quantity of her nickel ores have made Canada the world's most important source of supply of the metal. Its history and diversified uses are, therefore, particularly interesting at this meeting.

EARLY HISTORY

Probably the first use of nickel by man was in the fashioning of implements, and later swords, from nickel-bearing meteorites, masses of metal that have fallen from time to time at many points on the earth's surface and which consist normally of iron carrying substantial amounts of nickel.

Meteorites were perhaps the first metal known to man. The falling star, sought out with fear overborne by curiosity, was found to be a better stone than the earth-given, truly a boon from the gods. Archæologists tell us there is good evidence that the ancient oriental peoples learned at an early date to make these stones into useful implements.

The invincible blades of the great warriors of old, in China, Persia, and in northern Europe, were 'Heaven-sent', a fable which sounds significant of meteoric iron. Probably some of the ancient swords of Khorassan and of Damascus were of meteoric nickel-bearing iron (¹).

---

*President, The International Nickel Company, Inc.

(¹) Zimmer, G. F., Jour. Iron & Steel Inst., 1916 (2), p. 306.

Fifty centuries were to pass before man learned to isolate nickel and add it to iron to produce the same alloy for much the same purpose.

Meanwhile, man had found another natural alloy of nickel, known first to the Chinese as *paktong* or 'white copper'. It was obtained from complex copper-nickel-sulphide ores of Yunnan in southern China. This metal was brought by caravan through India into Bactria, a country north of the Hindu-Kush mountains, in what is now known as Russian Turkestan. The earliest specimen extant is a Bactrian coin of date 235 B.C.

The rough reddish-white metal was also sent in the form of triangular rings to Canton, where zinc ores were added and the whole smelted to a more malleable alloy, also known later as paktong. This alloy was the forerunner of German- or nickel-silver. Specimens of this alloy, wrought into ornamental candlesticks and boxes, were brought from Canton to Europe by the East India Company in the early days of the China trade. Paktong was highly prized for its beauty as well as its Eastern origin in far-away China. By 1760 the unwrought metal was imported into England for domestic manufacture.

While English craftsmen were attempting to rival delicate Chinese workmanship in the strange new metal, miners in Sweden and in Germany were discarding quantities of its mother ore. At Schneeberg, in Saxony, where from times immemorial silver and copper mines had existed, fresh lodes of ore were laid open, so glittering and full of promise as to cause the greatest excitement. After innumerable trials, and endless labour, instead of virgin-white precious metal, ductile, malleable, and indestructible by fire, all that could be obtained from the ore was a worthless metal, brittle and friable under the hammer(1). In disgust, the superstitious miners named the ore *kupfer-nickel,* after 'Old Nick' and his mischievous gnomes, who were supposed to have plagued the miners and bewitched the ores.

---

(1) Bonnin, A., Tutenag and Paktong; Oxford University Press, 1924.

After wrestling for five years with a similar ore from Helsingland, Cronstedt in 1751 succeeded in extracting a new element which he named *nickel.* Wherever the news spread the epithet tenaciously clung to the new element. In all languages, its name remains nickel.

Cronstedt's results were challenged by a number of experimenters, until, in 1775, after a laborious series of investigations, Bergman confirmed them. Almost thirty years elapsed before Richter produced the first pure nickel. Bearing in mind the difficulties under which work had to be carried out in those days, Richter's description of the properties of nickel, in 1804, is a marvel of accuracy(1).

It was not until after Cronstedt's discovery and Bergman's work that von Engeström, in 1776, discovered nickel in the famous paktong(1). For a time, manufacturers had visions of great profits from a domestic paktong. An arms factory at Suhl, near Erfurt, in Germany, succeeded in recovering copper-nickel from the slag dump of an old copper works to form a white alloy for gun furniture. The struggle with the obstinate ore went on for fifty years before a satisfactory imitation of paktong was produced.

In 1824, the brothers Henninger, of Berlin, placed the first imitation paktong on the market. About the same time, Geitner, of Saxony, produced a similar white metal, which he named *argentan.* In 1830, one Guiticke brought from Berlin to Sheffield, England, a sample of the synthetic silver-like metal. The generic term for these alloys thereafter became German-silver.

The refining of nickel in England dates from the year of Guiticke's visit. The first efficient substitute for paktong known in England was Merry's *metal blanc,* produced at Birmingham in 1832 by Henry Merry and Charles Askin; the latter one of the founders of the present firm of Henry Wiggin & Company, Ltd. Many German-silver paktongs were soon flourishing under a variety of trade names, including *electrum,* produced by Messrs. Topping of London, about

---

(1) Hadfield, R. A., Alloys of Iron and Nickel; Minutes of the Proceedings of Inst. Civil Eng., 138, 1-167, 1899.

1850. As production increased and the composition of the alloy became a matter of common knowledge, less paktong was imported from the East.

The advent of electro-plating made an important change in the uses of nickel. One of the first commercial applications of Faraday's great discovery of obtaining electricity from magnetism was in the use of an electro-plating machine constructed by Messrs. Prime & Company, of Birmingham, in 1844. Electro-plating had a twofold effect on nickel: one in introducing silver-plated ware with a German-silver base, in competition with the more expensive Sheffield plate; and the other, nickel-plating itself. Of the two, silver-plating on German-silver was the more important, and the practice then established remains today one of the prominent uses of nickel.

Although Boettger, as early as 1843, discovered that a bright electro-deposit of nickel could be produced using nickel ammonium sulphate, the difficulty of obtaining the metal for anodes in a sufficiently pure state effectively prevented commercial development of nickel-plating until about 1870. This use of nickel, although the best known, has at no time been of more than secondary importance. A small quantity of nickel, if spread in gossamer thinness, will make a large display.

During the first fifty years of active work with nickel, German-silver, later known as nickel-silver, was almost the only form in which nickel was used commercially. In 1850, the Swiss Government decided to use German-silver as the carrier of real silver in token-money coinage. There was great difficulty in both smelting and rolling the alloy. The coins were too hard to take a good impression, and lacked lustre.

In 1859, a Belgian commission on currency reform effectually assailed the theory, then prevailing, that the intrinsic value of token money must approximate its nominal value. Consequently, after a thorough investigation of various compositions, a seventy-five—twenty-five copper-nickel alloy was recommended on the basis of economy, as well as appearance and workability. Belgium adopted this composition in 1860. The United States, which in 1857 had substituted an eighty-eight—twelve copper-nickel composition for the heavy copper penny, adopted a seventy-five—twenty-five composition in 1865. Germany did likewise in 1873, and Switzerland in 1879. Pure nickel coinage did not appear until 1881, largely due to lack of knowledge of the malleability of pure nickel.

The great contribution of Joseph Wharton to the metallurgy of nickel was the first production, in 1865, of malleable pure nickel. Up to that time nickel had been employed only in alloys. Wharton carried out the earliest experiments which were successful in producing nickel in a pure malleable condition, susceptible of being worked under the hammer. In 1873, he sent to the Vienna Exposition samples of nickel forgings, and at the Exhibition in Philadelphia, in 1876, he displayed a remarkable series of objects made of wrought nickel. These were also exhibited in Paris in 1878.

The same year, Fleitmann patented the method of obtaining malleability by adding small amounts of magnesium to the melt. He later patented the use of manganese for the same purpose. Nickel so treated was rolled into sheets and drawn into wire. Fleitmann also succeeded in rolling sheet nickel upon iron, and also upon steel plates, much as silver is rolled on copper in making Sheffield plate. These developments led to the manufacture of nickel culinary ware, and here again Fleitmann, at Schwerte, was the pioneer in what has become an active and extensive industry.

Until the mining of nickel ores on the island of New Caledonia got well under way, about 1877, ores were sought all over the world—in China, South Africa, and South America. The supply of nickel was so scant that ores containing as little as one per cent of nickel were profitably worked. The sources of nickel in Europe were at first chiefly the arsenical and silicate ores of mines in Saxony, where, as already stated, kupfer-nickel had been discovered and named before the isolation of the metal in 1751. By 1873, these mines were sufficiently prosperous to employ 1,200 men in the mines and smelters. Some ores were also obtained in France and Sweden.

In Great Britain, nickel-sulphide ores were mined in Cornwall from 1852 onward, and also in Scotland and in Wales. In the Russian Ural mountains, nickel-serpentine (garnierite) deposits were worked as early as 1866, with a small production at various times. Mines containing similar ores, in Italy, Spain, and Austria, were actively producing in the 'seventies.

In Norway, mining of pyrrhotite-chalcopyrite ores, similar to those of Sudbury, Canada, began in the 'forties and reached its greatest importance in the period 1870-1877. Norway controlled the nickel market prior to the advent of New Caledonia as a producer.

In the United States, mines were worked in Connecticut, Missouri, and Pennsylvania. The pyrrhotite ores of Litchfield county, Connecticut(1), discovered in 1661, were shipped to China about one hundred years later, and in 1818 to England. The ores of Mine La Motte, Missouri(2), worked by French explorers as early as 1719, were shipped to nickel refiners in England about 1830-1850. They failed to become a prominent factor, however, due to difficulty in separating nickel from lead. The important mine in the United States was at Lancaster Gap, Pennsylvania(3). Nickel ore from this mine was not treated until 1850, although the mine had been worked previously for copper. Refining was first started in Philadelphia, but operations were transferred to Camden, New Jersey, in 1853. Joseph Wharton leased the Camden works in 1863 and purchased them in 1869.

By 1887, the competition of New Caledonian ores had brought all other nickel mining, save that in Norway, to a standstill. Garnier had discovered the New Caledonian deposits in 1865, but their momentous value and extent were not realized until the geological survey reports were published in 1874. During the next fifteen years, New Caledonia was the principal source of nickel for an enormously increasing demand.

---

(1) Blake, W. P. U.S. Geological Survey, 1883, pp. 399-407.
(2) Keyes, C. R. Missouri Geological Survey, 1894, vols. 6, 7, and 9.
(3) Blake, W. P. Trans. Amer. Inst. Min. Eng., 1883, XI: 274-281.

The occurrence of nickel ore in Canada was reported as early as 1848. In the Sudbury district, the first authentic discovery was recorded about 1856. At that time the country was a vast wilderness, and it was not until the advent of the railway, twenty-seven years later, that clearing and exploration began. Sudbury was at that time the terminus of the Canadian Pacific railway, from which point construction was being pushed westward. In the course of this work, a cutting was made which passed through an outcrop of copper ore that was later to be the Murray mine. Prospectors after copper immediately flocked into the surrounding country, and a very large number of claims were staked. The rich copper-ore discoveries made on the line of the Canadian Pacific stimulated Mr. Ritchie, who had built the Central Ontario railway, to go to Ottawa in search of tonnage for his railway. He soon became interested in, and purchased, the holdings of McAllister, Metcalf, Frood, Creighton, McConnell, and, later, the Evans and Crean Hill properties, which led to the organization, in 1885, of the Canadian Copper Company, with Mr. Ritchie as its first President.

When mining operations were begun, the owners were still unimpressed by the presence of nickel in the ore. Colonel R. M. Thompson of the Orford Copper Company, at Constable Hook, New Jersey, contracted to smelt the ore, but he soon found that the copper would not come out. All that could be obtained was a worthless alloy—a repetition of the experience of the German miners a century previous.

While Colonel Thompson was wrestling with the problem of the separation of the nickel and copper, which was subsequently solved by the Orford, and later by the Mond, process, Mr. Ritchie had to face the problem of creating a market for his nickel. The world's annual consumption of nickel in 1886 was about one thousand tons, whereas the rich ores of his Canadian mines were ready to turn out twice that amount. The price, which had been $2.50 per pound in 1876, was only 16 cents per pound in 1886. (See Figure 2, insert). The market was heavily overstocked. German-silver, electro-plating, and coinage were practically the only uses for the metal. The future of the Canadian industry depended upon the extension of the market by finding new uses for nickel.

At this juncture, Mr. Ritchie recalled an experience ten years before in Washington. He had met there John Gamgee, an Englishman, who had interested the Government in the building of a refrigerated hospital ship for treatment of yellow-fever patients in the Gulf ports. Gamgee investigated ammonia refrigerating machines, but soon found that cast iron would not hold compressed ammonia gas. He tried all kinds of alloys. Then, going one day through the Smithsonian Institute with Mr. Ritchie, he saw some nickel-iron meteorites, and decided to try such an alloy. Mr. Wharton furnished some nickel, with which Gamgee produced a very superior nickel-iron alloy, which held the gas. Gamgee's ship was never built, but he had demonstrated the possibilities of nickel-iron alloys. Of all the possible uses, nickel-iron alloys caught Mr. Ritchie's imagination as the most promising. Faraday had alloyed nickel and iron in 1820. Wolf, Liebig, Fairbairn, and Thurber had called attention to the properties of these alloys. Sir Henry Bessemer, in 1858, had tried to produce 'meteoric-iron guns'. Parkes, of Birmingham, had patented nickel-iron alloys in 1870.

Ritchie wrote to the famous gun-maker, Krupp, at Essen, telling him of the remarkable corrosion-resistant alloy Gamgee had produced, and asking him about the possible use of nickel-iron in gun manufacture. In the reply from Krupp, the matter was treated lightly and the belief expressed that there was not a sufficient quantity of nickel in the world to warrant experiments looking to any extended use of the metal. However, nickel-iron alloys were being thoroughly investigated at that time. The appearance of chrome-steel projectiles, made in France about 1886, had shown high penetration against wrought iron and compound armour plate, the best protection then known by the leading navies.

Marbeau, of La Société Ferro-Nickel, of Paris, had attracted the interest of British armour-plate manufacturers by his production of ferro-nickel and nickel-steel at the Montataire works in 1885-1887, and Mr. James Riley, manager of Tennant & Sons Steel Company of Glasgow, was commissioned to investigate. His results were presented in his now famous paper of 1889, on the 'Alloys of Nickel and Steel'. In the discussion of the paper, J. F. Hall, of Sheffield, reported independent work confirming Riley's results.

Mr. Ritchie brought this report to the attention of the Secretary of the Navy of the United States. Its importance was immediately recognized. Lieutenant Buckingham, of the United States Navy, and Sir Charles Tupper, of Canada, accompanied Mr. Ritchie abroad to gather further information. They visited a number of the leading steel and ordnance makers in Great Britain and Europe, as well as the principal companies engaged in the production and refining of nickel. They found all very much aware of the importance of nickel, and several who were obviously desirous of gaining control of the new deposits or their output.

As a result of the reports on this investigation, the United States Navy ordered a nickel-steel plate and a plain steel plate from Le Creusot works of Schneider, in France, and also a plain steel plate such as was then used by the British navy, from Cammell & Company, of Sheffield. At the trial of these plates, in 1891, the nickel-steel proved decisively superior. The results were immediately of great interest all over the world. The United States Congress appropriated a large sum of money for the purchase of nickel, to be used in making nickel-steel armour plate for the navy.

The next ten years witnessed intensive research on the properties and treatment of nickel-steels. By 1900, there was available to engineers much sound and useful information, as evidenced by Hadfield's exhaustive paper before the Institute of Civil Engineers, in 1899, on the 'Alloys of Nickel and Iron'.

Soon the exacting requirements made necessary additional studies of steel applications and properties. In detail of knowledge and in care of procedure, these studies added a further important fund of information on the nickel-steels. Second to ordnance, and growing simultaneously with it, came bridge building, and then the automotive uses of nickel-steel.

This condition continued without a break up to the opening of the World War, in 1914. German-silver, nickel-plating, pure nickel and copper-nickel coinage, though consuming large quantities of the metal, had become relatively of less importance than in former years as a result of the increasing demand for nickel for the great navies, and for ordnance, bridge building, and the automobile.

The war created an unparalleled demand for the metal. The Canadian mines extended their resources to the utmost to furnish nickel for the Allies, and every effort was made to speed up production. Industrial uses were neglected in order that ordnance demands might be supplied. Germany commandeered nickel cooking utensils and nickel-bearing coinage. Old German mines were reopened. These, with the added production, until 1916, from Norway, were Germany's sources of supply.

The Armistice in 1918 brought to a close a four-year period of high-pressure production. It also brought to a close a longer period, of about fifteen years, during which the steadily increasing prosperity of the industry had been based largely upon the building of great navies and equipping great armies. The effect of the armistice was not fully realized until the completion of war contracts in 1920. The graph of annual nickel production is a mute witness to the heavy deflation of 1919-1921. (See Figure 1, insert.) The total world production of nickel fell back to what it had been about 1900.

With the close of the war, the nickel industry faced the problem of creating new markets. Once before, adequate uses for nickel had been developed where there seemed to be none. The conditions at the end of the war were similar to those confronting Mr. Ritchie in 1889. The nickel producers realized that their efforts must again be centred on a well directed, vigorous search for uses for nickel.

MARKET DEVELOPMENT IN THE POST-WAR PERIOD

The new era, although not as yet at maximum war consumption, appears to offer fully as great promise as any preceding one. It may be characterized as the period of market development and stabilization in the industries of peace.

There are three principal contributing factors: a general intensification of engineering activity along all lines, stimulated by the war; the active interest and effort of the nickel-producing companies; and the increase in automotive production.

Unprecedented Engineering Activity:

The present industrial period is one of unprecedented engineering activity and research, which we recognize as a legacy, in part, from the war. Certainly, urgent engineering military requirements—airplanes, submarines, gas-warfare equipment, etc.—stimulated to a high pitch all the engineering thought and activity of the nations. The war-period achievements of research and invention spread to all industries, and the momentum of this activity has not subsided since the war. It has been effectively applied to the problems in reconstruction of industry rising out of the disturbing post-war depression.

With reconstruction has come rapid development of improved machinery and construction of all kinds. There has been a demand for improved and special materials of construction. There has been also a new receptiveness on the part of the engineer, almost an eagerness, to give careful and constructive consideration to all such new materials, an attitude in contrast to that of definite conservatism existing before the war.

This is the soil in which the new nickel market has grown and flourished. The recovery of nickel consumption probably could not have occurred so rapidly except for this exceptionally favourable atmosphere of engineering interest and liberalism.

Many industrial applications of nickel products have been favoured by this new situation. Some of the more striking examples are: the rapid development of the use of the nickel-chromium 'heat-resisting' alloys; the discovery and use of the remarkable magnetic nickel-iron alloys of the 'permalloy' type; the development of nickel cast iron; and the increased diversity of uses of monel metal.

Active Interest and Effort of the Nickel Producing Companies:

During the life of the present nickel-producing companies, their interest and effort had, up to 1919, largely been directed toward the economic production of the metal in rapidly increasing tonnages. Only once in the past had their effort been exerted effectually in developing the nickel market, namely, during the 'nineties, when the industrial use of nickel-steel was established for armour plate and ordnance.

When the market thus created collapsed in 1919-1921, the producers realized that their effort must again be directed to the discovery of new uses for nickel. They saw clearly that the large demand for war purposes was at an end, and that new industrial fields must be found to fill the gap. Since the war, development of a market for nickel has been the prominent activity of the nickel producers.

This activity in markets has taken all of the usual directions, including increased sales effort and advertising, as well as increased attention to quality of products. One feature, however, which is new, at least within the industry, deserves special mention. This is the creation of new uses, and the extension of those already established, by engineering development and research in the market field (1).

Nickel products are used largely for engineering purposes because they possess certain definite and valuable engineering properties, often highly special in character. The placing in the hands of engineers generally, of accurate detailed information and data on the various nickel products, has been an important part of the programme. The principal engineering groups and executives have been given information on the possibilities of nickel products for use in their designs and constructions. This has been done by personal contact, by engineering bulletins, and by special articles in the engineering press.

Another part of this type of activity is the development of new and useful products of nickel through research. Many new products of nickel are possible, as well as industrial fields of usefulness for them. To develop them, the nickel producer, who is the most interested party, must assume the burden of the work. An excellent illustration is the case of nickel in cast iron.

---

(1) One of the nickel producers organized at once a special Department of Development and Research, to carry out this effort. All the principal producers now have similar organizations.

Sir William Fairbairn suggested the improvement of cast iron by addition of nickel as early as 1858, and Guillet, in 1907, described its essential beneficial effects. Yet no industrial development, based upon these experiments, took place. No one was interested.

Not until one of the nickel producers took up this matter, investigated it thoroughly in his laboratories, and demonstrated the value of nickel in practical foundry operations, was there any real industrial use of nickel for this purpose. Today, some two hundred tons of nickel are sold for it yearly, and the use is increasing rapidly.

Influence of the Automotive Industry:

Every metal industry has profited by the phenomenal growth during the past fifteen years of the automobile industry, and nickel is no exception. There has been a rapidly increasing consumption by this industry of nickel in many forms, principally nickel-steel and nickel-plating. Nickel has profited indirectly as well from the favourable effect which automobile development has had on engineering activity generally, in stimulating search for and consideration of new materials and in maintaining the present progressive and liberal attitude toward new developments. Without doubt, the automotive engineer has been the most prominent engineering pioneer in industry during the past fifteen years.

THE PRESENT INDUSTRIAL USES OF NICKEL

The diversification of use of nickel during the post-war period is the most remarkable episode in recent nickel history. A brief outline of the growth during recent years will be of interest. It has already been pointed out that the major portion of nickel used in 1913 was for armour plate and ordnance. In 1926, with a larger total consumption, the nickel used throughout the world for military and naval purposes was probably not over ten per cent of the whole. The large use for war materials has been replaced by industrial applications.

GROWTH OF INDUSTRIAL USES OF NICKEL

	Date of origin	Names associated with origin	Substantial use began about	Percentages of world's market, 1926
Group 1:				
Nickel-silver	'Paktong', very early, in China.	Geitner, Henninger, Merry, and Askin	1830	15
Coinage	235 B.C.	Bactrian coin	1850	2
Nickel-plating	1843	Boettger	1870	5
Structural nickel steel	1889	Marbeau, Riley, Hall, and Hadfield	1890	35
Group 2:				
Copper-nickel alloys (other than coinage and monel metal type)	1895	Feussner and Lindeck	1900	2
Nickel catalyzers	1896	Sabatier and Senderens	1905	1
Nickel for Edison storage batteries	1901	Edison	1905	2
Monel metal type	1905	Ambrose Monell	1906	20
Heat-resisting and electrical alloys	1906	Marsh and Placet	1910	5
Group 3:				
Malleable nickel	1865	Wharton and Fleitmann	1912	5
Nickel-steel castings	1896	Wedding	1915	2
Nickel bronze	1900	Clamer	1920	1
Corrosion-resistant steels (nickel-chromium)	1919	Pasel and Johnson	1920	1
Ferro-nickel alloys	1895	Dumas, Benoit, and Guillaume	1925	2
Nickel cast iron	1907	Guillet	1925	1
Miscellaneous alloys (aluminium, white gold)	....	....	1920	1

Group 1 —In substantial industrial use in 1900.
Groups 1 and 2 —In substantial industrial use in 1918.
Groups 1, 2, and 3—In substantial industrial use in 1927.

If we take the arbitrary classification of the table on the opposite page(¹) as a basis of analysis, we note sixteen definite classes of nickel products and applications in use today, compared with nine in 1918 and four in 1900. Furthermore, there is, within several of these industrial classes, much greater diversification today than ever before, particularly in nickel-steel, nickel cast iron, nickel-chromium alloys, nickel-copper alloys, monel metal, and malleable nickel.

It is obvious that nickel has a very wide field of application. There are probably few metals with so great a variety of uses. Furthermore, these nickel products have taken their place as recognized standard materials with a constantly increasing industrial demand.

Tables I to III, on a later page, give a condensed statement of compositions and applications of the principal nickel products. It will be observed that there are listed fifteen primary nickel products and over sixty others. The fifteen (Table I) are the products of the nickel producing companies themselves and are their principal products. The sixty-nine industrial products (Tables II and III) have been arbitrarily and conservatively chosen from hundreds of compositions made throughout the ferrous and non-ferrous industries(²).

A few words may be said concerning these different groups of industrial nickel products, with particular reference to the more recent developments and to the engineering reasons for their use.

Nickel-silver:

Nickel-silver is one of the oldest established uses of nickel and is still a very substantial one. The industrial applications of this material have not changed very much in recent times. There is, however, one development worthy of notice, namely, the development of compositions of nickel-silver that can be hot-worked. The hot-rolling varieties are not essentially different in their valuable characteristics of appearance, corrosion-resistance, and ready fabricability from the other varieties, but they offer promise of somewhat cheaper production.

(¹) Some of the details of this table must be accepted as rather rough approximations, made for the purpose of presenting a clear and simple picture of the nickel market, past and present.

(²) In some of these, the use is limited to highly specialized applications.

The market development in this field is the increasing use of nickel-silver for ornamental and hardware castings, automobile trim, and domestic plumbing fixtures.

Coinage:

Coinage is also one of the oldest uses of nickel. The principal interesting development of recent times has been the substitution of pure nickel coinage for the older nickel-copper coinage started about 1850. Several countries, including Canada, have within the past few years adopted a pure nickel coinage, and are finding it better than the copper-nickel composition. It is harder, very resistant to wear, and a very clean coin. Because of its hardness and high melting point, it is difficult to counterfeit. In all, there are seventy-five countries throughout the world using some type of nickel coinage.

Nickel-plating:

Nickel-plating of iron and brass articles is perhaps the use best known to the general public. It is the form of nickel to which most minds turn when the word 'nickel' is mentioned.

Nickel-plating has for many years been rather an art than a science. It is carried out in a multitude of small plating shops under a wide variety of conditions. Within the last few years there has been a definite indication of improvement in the practice, through better control of the plating conditions. This, with improved methods of preparation of work for plating, has resulted in substantially better nickel-plated articles.

There is a recent definite trend toward heavier coatings of nickel. The old standard plate of nickel was no more than one ten-thousandth (.0001) of an inch. In consequence, the plate was readily worn off. Many plating shops today are putting on a coating as heavy as one thousandth (.001) of an inch. Experience has shown that heavier coatings will endure and preserve their appearance very much longer. The universal demand for better nickel-plating on automobiles has been responsible for this improvement in the art.

Structural Nickel-Steel:

Nickel-steels comprise the largest tonnage of industrial nickel products. Although the detail of their use has changed considerably during the past ten years, in consequence of the elimination of the armour plate and ordnance, this group has always been of first importance.

As is well known, the structural nickel-steels are used industrially because of their superior mechanical properties: strength and toughness. Some of the interesting recent developments are the increasing use of nickel-steel for heavy mill and power machinery; its introduction into railway and locomotive use, for axles, rods, boiler plates, and cast frames; and the increasing use for roller bearings.

Copper-Nickel Alloys:

There is today a considerable use of copper-nickel alloys. An important alloy of this group, ordinarily known as 'constantan', contains approximately forty-five per cent nickel. This alloy combines high electrical resistivity with a low temperature coefficient of electrical resistance. In addition, it has a uniform and reproducible thermal e.m.f. toward either iron or copper. By reasons of these virtues, constantan is used very generally for electrical resistance, rheostats, etc., as well as for industrial thermocouples and thermoelectric pyrometers.

It is also used, to a certain extent, for corrosion-resistant castings and sheet.

Nickel Catalyzers:

Sabatier and Senderens discovered, about 1896, that finely divided nickel would catalyze the hydrogenation of unsaturated hydrocarbons. This discovery is now generally used for the production of solid edible fats from liquid unsaturated oils, such as cotton seed and peanut oils. Nickel for this purpose is sold chiefly in the form of nickel salts, particularly the carbonate and formate.

Recently, Sperr has developed a process for the desulphurization of domestic coal-gas, which promises to utilize in the future a moderate amount of nickel catalyzer.

Nickel catalyzers have been proposed also for the cracking of petroleum, for the synthesis of higher hydrocarbons from acetylene, for the synthesis of alcohols from oxides of carbon, and also for the synthesis of ammonia and nitrates from nitrogen and its oxides.

Edison Storage Battery:

The well known Edison storage battery requires annually a substantial amount of nickel, both for the active chemical constituents of the cell and for the plating of the various steel parts of which it is made. This cell is increasing in popularity, being used today to a large extent for power units of automobile trucks, mine and railway cars, factory and warehouse trucks. There is also a more recent but growing use in the widespread radio field.

Monel Metal:

The corrosion-resistant copper-nickel alloy which now is generally referred to as 'monel metal'(1) first made its appearance in 1905, but it was not until recent years, during the period of active market development, that it achieved its present substantial consumption. Back of, and underlying, the whole effort has been the engineering study of the technical suitability of monel metal to each proposed new use. This technical foundation work has been supplemented currently by engineering field service in solving fabrication and corrosion problems.

Monel metal and similar alloys have a very diversified application today in practically all industrial fields. The most recent interesting developments are: refrigerator trim; hotel, restaurant, and cafeteria equipment; various types of food-handling equipment; bleaching and dyeing equipment; in laundry machines; and in equipment for handling steel in pickling solutions. Wherever, in fact, a corrosion-resistant material of good appearance and good mechanical properties is needed, monel metal is used.

The erecting of modern rolling mills, devoted exclusively to the production of this high-nickel nickel-copper alloy, and malleable nickel, has been of the first importance. The improved quality of the product in malleability, conformity to engineering standards, and in finish, has opened the way to monel metal in many fields of use.

---

(1) Although this is, accurately speaking, a registered trade mark.

Heat-Resisting and Electrical Alloys:

The heat-resisting and electrical alloys include principally the alloys of nickel with chromium and iron. Their merit consists in resistance to scaling and oxidation at high temperatures, superiority to steel and other alloys in mechanical properties and strength at these temperatures, and also high electrical resistance.

Following their discovery by Placet and Marsh, these alloys were developed first for electrical heating wires in household appliances, such as toasters, percolators, irons, etc. They have now been adopted in all fields of high-temperature construction, in fact in all industries using fuel. They are used in many structural forms: as castings, plates, sheet, pipe, etc. They are meeting a vital engineering need which has become increasingly urgent in recent years.

Malleable Nickel:

Nickel in forged or rolled form, or 'malleable nickel' as it is usually called, has been known since 1865. Yet the extent of its manufacture until recent years has been small and its commercial use restricted to wire, coin blanks, and cooking utensils. It is now, however, finding much wider employment, as for hotel and restaurant cooking utensils, and also in dairy and chemical equipment. The recent development of seamless malleable nickel tubing has done much to further its use in the chemical and food industries.

Nickel Bronzes:

Perhaps the first application of nickel in the brass foundry was its use in high-lead-bearing bronzes, to prevent lead segregation. Such an alloy was introduced by Clamer, about 1900, in the bronze commonly known as 'Ajax plastic bronze', the demand for which has grown steadily in recent years.

Small additions of nickel in bronze pressure-castings, to refine the grain and to eliminate porosity, is another principal use. Nickel is used in valve bronzes for the same purpose and also to improve hardness and strength at the operating temperature of steam valves.

Corrosion-Resistant Steels:

Early in the history of nickel-steel, investigators became aware of the corrosion-resistance of steels containing from twenty to thirty per cent nickel. There has been considerable use of such materials for various purposes where strength and substantial resistance to corrosion are required. More recently, it has been found that these nickel-bearing steels can be improved by the addition of chromium, and several types of chromium-nickel corrosion-resistant steels have come into use in the United States, in England, and in Germany. These steels, in addition to their chemical resistance, have excellent mechanical properties with great strength and high fatigue resistance.

Ferro-Nickel Alloys:

There are numerous ferro-nickel alloys and they exhibit the greatest diversification of characteristics and properties. Those containing from thirty-six to forty-five per cent of nickel are characterized by abnormally low thermal expansion. They have long been known under the names of 'invar', 'platinite', and other trade names. Invar is used in various kinds of measuring instruments and equipment. Platinite is used extensively in the tungsten filament lamp. A recent substantial use of invar is in the construction of the compound aluminium-invar automobile piston. In this, advantage is taken of the lightness of aluminium and its excessive expansion is counterbalanced by the low expansion of invar, the result being a net piston expansion approximately equal to that of cast iron.

Another very interesting series of alloys in this group is the 'permalloy' type, containing fifty to eighty per cent nickel; and valuable because of extremely high magnetic permeability at low field strengths. They were developed first by the Western Electric Company and used for cable sheathing. By the use of these alloys it has been possible to increase the rate of sending messages about one thousand per cent. In addition, they are being used in increasing amounts for radio transformers, for relay and other work requiring highly magnetic materials.

At the other extreme may be mentioned non-magnetic nickel-steel alloys carrying fifteen to twenty per cent nickel, often with some chromium, which are valuable chiefly in electrical machinery on account of their good mechanical properties and the absence of ferro-magnetism.

Nickel Cast Iron:

One of the latest ferrous nickel products is nickel cast iron. For many years something has been known about the effect of nickel in grey cast iron and there has been some isolated production of it. The application amounted to very little before 1925. It is a development with which my Company has been particularly concerned and active. Although the consumption of nickel for this purpose is still small, it is growing rapidly, and it may be said that the manufacture of nickel cast iron appears to offer promise of a substantial outlet for nickel in the future.

Nickel added to grey iron gives it increased hardness, wear-resistance and strength together with improved machinability.

Miscellaneous Alloys:

Nickel appears to be a favourite alloying element with inventors who are developing new industrial alloys. It is interesting to note the frequency of its occurrence in current patent specifications for alloys of all sorts. Campbell, in 1922, published a list of alloys comprising approximately fifteen hundred, of which about four hundred and fifty contain nickel. Some have merely an academic interest. A large number, however, are the staple alloys of commercial use. Two of these alloys may be chosen for illustration: nickel in aluminium die cast alloys, and in the well known 'white gold'.

The use of approximately four per cent of nickel in aluminium die castings serves to improve the casting properties of the alloy in chilled molds and to give it improved colour and structure.

In gold, nickel serves as a decolorizer. Fifteen to twenty per cent, added to gold, produces a white alloy similar in appearance to platinum. 'White gold' is widely used today to replace the less popular yellow gold.

CONCLUSION

In conclusion, I will review briefly the steps by which an industry of war has become an industry of peace. Swords into plow-shares has been a real experience in the nickel industry. From 1890 until the end of the World War, the building of great navies, with accompanying ordnance, created a demand for nickel in ever increasing quantities. From 1914 to 1918 this increasing demand reached its peak. Every source of nickel was tapped. The whole effort of the nickel industry was focused on getting out enough nickel to satisfy the demand. With the end of the war, the bulging market for nickel shrank to a fraction of normal. There were two possibilities available to the nickel producers to meet this serious change in market: economies in production costs, and development of more industrial uses for nickel and its alloys.

Europe, occupied in stanching the wounds of war, could not immediately enter upon an era of industrial development. The immediate market was America. With the pressure for production removed, economies were installed, resulting in substantial lowering of production costs. The quality of the products was improved and new ones were brought out, suitable for new industrial uses. The building of rolling mills, especially designed for the rolling of nickel and monel metal, made them available in quantity, and with superior strength, uniformity, appearance, and corrosion-resistance.

Information on all nickel-bearing products was carried to industrial engineers, offering service and co-operation. Engineers were looking for better materials. The war had stimulated unprecedented engineering thought and research. New products were eagerly investigated. A foundation was carefully laid upon which substantial commercial activity was built. This method, used in both the ferrous and non-ferrous fields of opportunity, proved practical and effective.

In short, through active effort of the nickel companies, with the assistance and co-operation of the metal industries generally, peace-time uses of nickel have been increased, with a resultant satisfactory recovery in the nickel market.

Manufacturing policies today include serious consideration of supply of raw materials for the years ahead. There is not only the question of will this or that material build a better machine, but also as to whether there is plenty of it readily available. For nickel, this question has been answered in the affirmative by Nature's lavish deposits in Canada. There is enough nickel ore, of good quality, in the Ontario mining area alone, to supply the world's needs at the present rate for well over one hundred years.

The nickel industry has entered the new era on a sound footing — well equipped in resources, with high-quality products and the right method to develop its market. The future years are full of promise.

APPENDIX

The published prices of metallic nickel for the years 1840-1926 are shown in the chart, Figure 2. In Figure 3 the prices during the period 1903-1926 are plotted on an enlarged scale, and prices of other metals are included for convenience of comparison.

TABLE I—FORMS OF NICKEL COMMERCIALLY AVAILABLE

No.	%Ni	*Primary Nickel Products*
A	99.00*	25-lb. and 50-lb. pigs, for remelting in production of steel.
B	99.00*	Shot nickel, for remelting in production of alloys.
C	99.80	Pellets, for remelting in production of steel and alloys.
D	99.90*	Electrolytic nickel of highest grade, for remelting in production of alloys.
E	99.50*	Reduced, or grain, nickel, for solution in acids in nickel salts production.
F	92.00	Low melting point (F) shot nickel, for ladle additions to cast iron.
G	99.50*	Nickel rondelles, for remelting in production of special alloys.
H	99.00	Nickel anodes for nickel plating.
I	95.00-97.00	" " "
J	92.00-95.00	" " "
K	20.80	Nickel sulphate, crystallized, for nickel plating.
L	14.80	Nickel ammonium sulphate, crystallized, for nickel plating.
M	44.00	Nickel carbonate, for catalyst.
N	77.50	Nickel oxide.
O	69.00*	Monel metal.

---

*Plus cobalt.

TABLE II

TYPICAL COMPOSITIONS OF INDUSTRIAL NICKEL PRODUCTS

(Note:—For trade names of compositions, refer to the references in appended bibliography under the heading 'Nickel and Nickel Alloys'.)

Nickel silver

Number	% Ni	% Cu	% Zn	
1	10.00	65.00	25.00	
2	12.00	54.00	21.00	2.50% Sn, 10.00% Pb
3	15.00	64.00	21.00	
4	18.00	65.00	17.00	
5	20.00	75.00	5.00	
6	22.00	61.00	12.00	1.50% Pb, 3.00% Al
7	25.00	55.00	20.00	
8	30.00	47.00	23.00	

Structural nickel steels
Nickel, nickel-chromium, nickel-molybdenum and nickel-chrome-molybdenum steels

Number	% Ni	% Cr	% Mo	% Fe
9	.50	....	...	Balance
10	1.50	....	...	"
11*	2.00	....	...	"
12*	3.50	....	...	"
13	5.00	....	...	"
14	.50	.90	...	"
15*	1.25	.60	...	"
16*	1.75	1.00	...	"
17*	3.00	.90	...	"
18*	3.50	1.25	...	"
19	4.50	1.50	...	"
20 *	1.25	....	.20	"
21 *	2.00	1.00	.25	"

*Used in several carbon ranges, from 0.10% to 0.50%.

Copper-nickel alloys

Number	% Ni	% Cu
22	2.50	Balance
23	5.00	"
24	15.00	"
25	20.00	"
26	25.00	"
27	30.00	"
28	45.00	"
29	68.00	"

Heat-resisting and electrical alloys

Number	% Ni	% Cr	% Fe
30	5.00	25.00	Balance
31	35.00	15.00	"
32	60.00	12.00	"
33	80.00	20.00	—
34	85.00	15.00	—

Nickel-steel castings

Number	% Ni	% Cr	% Fe	
35	3.00	....	Balance	Used in several carbon ranges, from 0.10% to 0.50%.
36	1.50	.75	"	
37	3.00	1.00	"	
38	1.50	(.20 Mo)	"	

Nickel bronzes

Number	% Ni	% Sn	% Zn	% Pb	% Cu
39	1.00	10.00	....	.25	88.50
40	1.00	2.50	7.00	5.00	84.00
41	1.00	5.00	....	30.00	64.00
42	5.00	9.00	2.00	....	83.00

Corrosion-resistant steels

Number	% Ni	% Cr	% Fe
43	2.00	14.00	Balance
44	7.00	20.00	"
45	8.00	18.00	"
46	16.00	10.00	"
47	22.00	7.00	"
48	30.00	.....	"
49	35.00	15.00	"

Ferro-nickel alloys

Number	% Ni	% Cr	% Fe
50	18.00	6.00	Balance
51	20.00	.....	"
52	30.00	2.00	"
53	36.00	.....	"
54	36.00	12.00	"
55	38.00	.....	"
56	50.00	.....	"
57	79.00	.....	"

Nickel cast-iron

Number	% Ni	% Cr	Cast iron
58	.50	.....	Balance
59	1.00	.....	"
60	2.00	.....	"
61	5.00	.....	"
62	.75	.35	"
63	1.25	.45	"
64	3.00	1.00	"
65	1.00	2.00	"
66	13.00	(6.00 Mn)	"

Nickel-aluminium alloys

Number	% Ni	% Cu	% Si	% Al	% Mg
67	4.00	4.00	2.00	Balance	....
68	2.00	4.00	....	"	....

White gold

Number	% Ni	% Zn	% Au
69	15.00	5.00	Balance

TABLE III

PRINCIPAL INDUSTRIAL USES OF NICKEL AND NICKEL PRODUCTS

Nickel-silver (Nos. 1-8, containing 10-30% nickel):

Standard white-metal, for silver plated ware, particularly spoon stock, dishes, platters, miscellaneous jewellery and bric-a-brac; for key stock and white-metal hardware; for valves, cocks and domestic plumbing fixtures; for springs and for electrical wire; for soda-fountain cabinets, counters and trim.

Nickel-plating:

Nickel anodes and nickel salts used in electroplating of nickel on brass and steel products of the widest variety: automobile radiator shells and hardware, miscellaneous domestic appliances and utensils.

Structural nickel steels (nickel, nickel-chromium, nickel-molybdenum, nickel-chromium-molybdenum; Nos. 9-21, containing 0.5-5% nickel):

Automobiles, motor cycles, buses, trucks, tractors, and airplane motors: for rear axle and transmission gears, rear and front axles, crank and cam shafts, frames, roller bearings, silent chains, bolts, connecting rods, steering knuckles.

Heavy mill machinery: hydraulic press columns, cross-heads, hammer piston rods, cast and forged rolls, die-blocks, shear blades.

Prime movers and power machinery: turbine rotor forgings, turbine blading, reduction gears, marine crank and turbine shafts, pump shafts, roller bearings, chain drive, high-pressure steam valve bodies and trim.

Railways: locomotive frame castings, forged main and side rods, valve gear, axles, roller bearings, boiler plate, boiler tubes, staybolts, engine bolts, cast crossings, frogs and switch points.

Mining and excavating machinery: cast racks and pinions, cast crusher jaws, forged and rolled shafts, cast and forged gears.

Tools: die-blocks, punches, track chisels, band and disc saws, oil well drilling-bits, cutters, jars and couplers, shovels.

Machine tools: shafts and spindles, gears, chains.
Agricultural machinery: cast tractor shoes, sprockets, gears, shafts.

Bridge construction: structural plates and shapes, eyebars.
General machinery: heat-treated forgings, gears, axles, shafts, chains, roller and ball bearings.
Military and naval: armour and deck plate, gun forgings.

The copper-nickel alloys (of varied composition, Nos. 22-29, containing from 2.5-70% nickel):

For projectile driving bands and bullet jackets, for coinage (No. 26), the U.S. five-cent piece, for valve bodies and valve trim, for pyrometer and rheostat wire, for sheets, rods and castings resistant to corrosion.

Nickel catalysers:

Nickel in finely divided, reduced form (made from formate or carbonate), used in production of edible oils from unsaturated ones (cotton-seed oil principally); also more recently in connection with petroleum oil-refining.

Nickel for Edison storage batteries:

Nickel in metallic, oxide, and reduced form, used in the Edison cell, in radio units, and for auto-truck and industrial and mine-truck units.

Nickel-copper alloys, monel metal type (No. 29):

In food industries: for hotel and restaurant steam tables, sinks, counters, urns, shelving, dish washers, slicing machines; for meat packing, vegetable and fruit canning equipment, table covering, containers, knives; for ice cream tables, cabinets, freezers, packaging equipment; for artificial refrigerators; for soda-foundain cabinets, tops and trim.

In laundry machinery: washing machines, trucks, sorting tables.

In textile dyeing equipment: tanks, drums, vats, pails and dippers for dyeing and bleaching.

In chemical industries: tanks and crates for pickling steel, agitators, filter cloth, dryers, hoppers and chutes, conveying machinery, fans and blowers.

In coal mining: shaker screens, jig liners, pumps, valves.

In power machinery and equipment: pump rods and impellers, valves, valve trim, valve discs, turbine blading, springs, water and flow meters, for bolts and studs.
General: for hospital utensils, building roofing and hardware, automobile carburetter needles, spark plugs, photographic dark room equipment, marine hardware and fittings, propellers, cable and shafting.

Heat-resisting and electrical alloys (Nos. 30-34, also No. 28, containing 5-85% nickel):

In wire form for domestic heating units, toasters, irons, grills, percolators, etc.; for electric heat-treating furnaces; for pyrometer and rheostat wire.

In form of castings for carburizing boxes; for rabble arms and shoes in metallurgical roasting furnaces; for shafts and discs of continuous annealing and heat-treating furnaces; for interior furnace construction generally in enameling and heating furnaces; for retorts and tubes in the chemical industries; and for fuel carbonization and heat interchangers.

Malleable nickel:

In dairy equipment pasteurizers, tanks, milker pails, filling machines, butter and cheese packaging equipment; in hotel and restaurant cooking utensils; in the filament lamp, and in radio tubes; for automobile spark plugs.

Nickel steel castings (nickel, nickel-chromium and nickel-molybdenum, Nos. 35-38, with 1.5-3% nickel):

For railroad frogs, switch points, crossings, and locomotive frames; for tractor shoes and sprockets; for mill gear and guides, rolls, shear blades, pipe balls, piercing points; for high pressure steam and oil valves and valve trim; for rack and pinion movements; for rock crushers; for hammer die-blocks.

Nickel bronzes (Nos. 39-42, of widely varying composition, containing nickel from 0.5 to 5%):

For pressure castings, valves, lubricators, steam packing metal, heavy machinery bearings, worm gears.

Corrosion-resistant steels (of a variety of composition, Nos. 43-49, containing 2-35% nickel):

For pump rods, marine forgings and deck fittings, bolts, submarine periscope tubes, turbine blading, valves.

Ferro-nickel alloys (of a variety of composition, Nos. 50-57, containing 18-79% nickel):

Of low thermal expansion, for automobile pistons, electric filament lamps, thermostatic metal, fire-resisting glass wire reinforcement, surveyors' tapes, dimension rods, chronometers.

Of special magnetic properties, for submarine cable covering, low flux transformers, relays, non magnetic steel parts.

Nickel cast iron (Nos. 58-66, containing from 0.5-5 % nickel):

For automobile and truck cylinders, sleeves, liners, and pistons, steam compressor, pump and ammonia cylinders and liners, piston rings, oil and gas engine cylinders, hard gears and cams, thin-section manifold castings, resistance grids, hardware, machine tool, table and bench castings, grey iron wheels, flange couplings.

In aluminium alloys (Nos. 67-68, containing from 2-4% nickel):

For pressure die-castings, automobile steering spiders, vacuum cleaner bodies, miscellaneous hardware.

In white-gold (No. 69):

Used for jewellery, watch cases, rings.

A SELECTED BIBLIOGRAPHY OF NICKEL

It is obviously out of place to attempt here a complete bibliography of nickel, since it is at this date very highly specialized and quite extensive.

Circular No. 100 alone, of the United States Bureau of Standards, lists 1,300 references covering 1900-1923, with respect to uses and products of nickel principally.

The following references are selected for their general value and comprehensiveness, or as historical references.

Those marked with an asterisk include substantial bibliographies of the subject.

General

*"Report of Royal Ontario Nickel Commission", published by A. T. Wilgress, Toronto, 1917. A quite complete summary and history of nickel in all its phases: mining, smelting, refining, production, statistics, uses of nickel and its products, bibliography.

*"The Nickel Industry", by A. P. Coleman; Bulletin No. 170 of Canadian Bureau of Mines, 1913. A summary.

"The Nickel Industry", by P. D. Merica; Trans. Canadian Institute of Mining and Metallurgy, Vol. 29, 1926. A short summary, particularly of recent history and developments.

"The Mineral Industry", published yearly by McGraw-Hill Book Co. Contains each year a chapter on nickel, covering statistics and engineering progress.

"Mineral Resources of the United States", published yearly by U.S. Geological Survey. Contains each year a chapter on nickel.

Historical

"Observations and Experiments made with an Ore from the Cobalt mine of Loos in the Parish of Farila, Helsingland", by Axel F. Cronstedt; published in Kongl, Svenska Vetenshaps-Academiens Handlinger for ar 1751, Vol. 12, p. 287. The description of the isolation and discovery of nickel.

"A New, Perfect Metal Present in Entirely Purified Nickel", by J. B. Richter; Chem. Annalen, Vol. II, p. 383, 1803. Description of first preparation of nickel in pure form.

"Discovery of what in later years became known as the Creighton Mine"; Geological Survey of Canada, Report of Progress, 1853-56, pp. 168, 169, 176-181 (Report for the year 1856 by Alexander Murray.

"Alloys of Nickel and Steel", by James Riley; Jour. Iron & Steel Inst., Vol. I, p. 45, 1889. Generally regarded as the pioneer paper on nickel-steels, describing the earliest large-scale production of nickel-steels by Marbeau and tests by himself.

"Alloys of Iron and Nickel", by Robert A. Hadfield; Minutes of Proceedings of the Institution of Civil Engineers, Vol. 138, Session 1898-1899, Part IV, Sect. I, pp. 1-167, March 28, 1899. Description of the author's experiments and summary of knowledge on this subject, including also much history of nickel.

"Hydrogenation of Oils by Means of Nickel", by Sabatier and Senderens; Ann. Chim. Phys. (8), Vol. 4, p. 319, 1905.

"On the Manufacture of Ductile Nickel and Cobalt", by Th. Fleitmann; Ber. d. deutsch Chem. Ges., Vol. 12, p. 454, 1879. Description of the best method of producing malleable nickel and the use of magnesium.

"Tutenag and Paktong", by Alfred Bonnin; published 1924 by Oxford University Press. Contains account of the early history of nickel-silver.

"Use of Meteoric Iron by Primitive Man", by G. F. Zimmer; Jour. Iron & Steel Institute, 1916 (2), p. 306.

Mining, Smelting and Refining

*"Nickel", Metallhüttenbetriebe, Vol. II, by W. Borchers; Wilhelm Knapp, 1917, Metallurgy of Nickel.

*"Handbook of Non-ferrous Metallurgy", by Liddell; published by McGraw-Hill Book Co., Vol. 2, 1926. Contains review by A. J. Wadhams of present state of the art.

"Nickel Ores", by W. G. Rumbold; published by John Murray, London, 1923. A summary.

"The Mining and Smelting Operations of The International Nickel Company of Canada, Ltd."; Trans. Canadian Inst. Mining and Metallurgy Vol. 23, 1920.

"Nickel Refining by the Mond Process", by A. P. Coleman; Mining & Sci. Press, Vol. 107, p. 412, 1913.

"Electrometallurgie des Nickels", W. Borchers; published by Wilhelm Knapp, 1903.

"The International Nickel Company's Refinery Works at Port Colborne"; The Inco, Vol. I, No. 2, 1920; Eng. & Min. Jour., Vol. 107, p. 429, 1919.

"International Nickel Company's Refinery at Port Colborne"; Can. Min. Jour., Vol. 39, p. 262, 1918.

"Refinery and Rolling Mill for Monel Metal; Mech. Engrg., Vol. 45, p. 285, 1923.

"Nickel Refining in South Wales"; Anon. article in Metal Industry (London), Vol. 20, p. 147, 1922. Describing the Mond process.

"Fifty Years of Nickel Production by Basse and Selve"; Zeit. fur Metallkunde, Vol. 16, p. 448, 1924. A 50-year review of the activities of this Company, long active in the nickel business.

Nickel Steel and Iron

"Les Aciers Spéciaux", by Léon Guillet; Dunod et Pinat, Paris, 1904-1905. The classic discussion of the constitution and microstructure of nickel-steels.

*"Nickel Steel, Its Properties and Applications", by A. L. Colby; Proc. A.S.T.M., Vol. 3, p. 141, 1903.

"The Anomaly of Nickel-Steels", by Ch. E. Guillaume; Proc. Phys. Soc., Vol. 15, p. 54, 1920. A description of the peculiar properties, particularly thermal expansion, of high content nickel-steels, covering twenty years of the author's experience in this field.

"Alloys of Nickel and Cobalt with Iron", W. Guertler and G. Tammann; Zeit. fur Anorg. Chem., Vol. 45, p. 205, 1905. Investigation of iron-nickel alloys, particularly melting point.

*"Manufacture and Uses of Alloy Steels", by H. D. Hibbard; Bulletin No. 100 of U. S. Bureau of Mines, 1915. With excellent chapter on nickel-steel.

"Nickel-Steel for Bridges", by J. A. L. Waddell; Proc. Amer. Soc. C. E., Vol. 34, p. 726, 1908.

*"Die Spezialstähle" by Mars; published by Ferdinand Enke, 1922. Contains chapters on the nickel-steels.

*"Invar and Related Nickel-Steels"; Anon., Circular. No. 58 of the U. S. Bureau of Standards, 2nd edition, 1923. Complete summary and discussion of this group of nickel-steels, with bibliography.

"Steel and Its Heat-treatment", by D. K. Bullens; John Wiley & Sons, 2nd edition, 1917. Chapter on nickel-steels.

"Metallography", by S. L. Hoyt; McGraw-Hill Book Co., 1921. Chapter on special steels.

"S. A. E. Handbook", published yearly. Contains specifications and physical property charts of nickel and nickel-chromium steels.

"Nickel and Nickel-Chromium in Cast Iron", by T. H. Wickenden and J. S. Vanick; Trans. Amer. Foundrymen's Assoc., Vol. 33, p. 347, 1925.

Nickel and Nickel Alloys

*"Nickel and Its Alloys"; Circular No. 100 of the U. S. Bureau of Standards. Excellent description of the properties of nickel, nickel-steel and nickel alloys, with extensive bibliography (1900-1923); 1,300 classified references.

"Physikalisch-Chemische Tabellen", Landolt-Börnstein; Vol. I, Julius Springer, 1923. Contains constitution diagrams of binary nickel alloys.

"A List of Alloys", by William Campbell; Proc. A.S.T.M., Vol. 22, Part I, 1922. Contains extensive list of proprietary nickel alloys (among others) with chemical composition.

*"Physical Properties of Nickel", by D. H. Browne and J. F. Thompson; Trans. A.I.M.E., Vol. 64, p. 414, 1920. A review of existing data on this subject, with bibliography.

"Kent's Mechanical Engineers' Handbook"; published by John Wiley & Sons, 1923. Contains on p. 499 a chapter by W. H. Bassett including description of properties, composition, and uses of nickel-silver alloys; also a chapter by J. F. Thompson on monel metal.

*"Corrosion-resistant, Heat-resistant and Electrical-resistance Alloys"; a symposium of A.S.T.M., published in Proc. A.S.T.M., Vol. 24, Part II, 1924. Covering a variety of typical commercial nickel-bearing alloys of this type, particularly nickel-chromium and nickel-chromium-iron.

"Use of Nickel in the Brass Foundry"; published by The International Nickel Company in 1926.

"Development of the Use of Nickel in Coinage", by F. R. Barton; Jour. Inst. Metals, Vol. 36, p. 121, 1926. History and present practice.

"Nickel Coinage", by F. R. Barton; published by The Mond Nickel Co., Ltd.

Electro-plating with Nickel

"Chemische Notizen. 5. Einige Bemerkungen über das Vernickeln und Verplatiniren der Metalle auf galvanischem Wege". Rudolph Boettger; Erdm. Jour. für Praktische Chemie, XXX, pp. 267-271, 1843.

"Electrodeposition of Cobalt and Nickel", by O. P. Watts; Trans. A. E. S., Vol. 23, p. 99, 1913. Discussion of the art and extensive bibliography.

*"Principles of Electroplating and Electroforming", by W. Blum and G. P. Hogaboom; McGraw-Hill Book Co., 1924. Contains excellent chapter on nickel-plating.

*"Modern Electroplating", by W. E. Hughes; Hodder & Stoughton (London), 1923. Contains chapter on nickel-plating.

Series of articles published 1920-1926 from the U. S. Bureau of Standards by W. Blum and collaborators, on special technical features of nickel-plating; published monthly in Trans. A.E.S. during these years, viz., Vol. 39, p. 459, 1921; Vol. 41, p. 333, 1922; Vol. 42, p. 79, 1922; Vol. 44, 1923.

"Symposium on Electrodeposition"; Trans. A.E.S., Vol. 45, 1924. Series of articles by W. E. Hughes in Metal Industry (London) on nickel-plating, viz., Vol. 25, pp. 491, 543, 1924; Vol. 26, pp. 77, 137, 155, 1925; and Vol. 28, p. 457, 1926.

Other Uses of Nickel Products

"Operations and Care of Vehicle-Type Batteries; Anon., Circular No. 92 of U. S. Bureau of Standards, 1920. Deals with the Edison nickel hydrate cell.

"Report on Edison Storage Batteries for Submarine Service", published 1917 by Government Printing Office for Committee on Naval Affairs.

*"The Hydrogenation of Oils", by C. Ellis; Van Nostrand Co. 1919. A review of the whole subject including the action and use of nickel catalyst.

"Catalysis in Theory and Practice", by Rideal and Taylor; McMillan & Co., 1919.

PRECIOUS METALS IN THE SUDBURY ORES AND THEIR RECOVERY

BY C. LANGER, SR.* and C. JOHNSON*

(*Members, Inst. of Metals*)

(Toronto, Ont., Meeting, August 25th, 1927)

Although the existence of precious metals, particularly those of the platinum group, in the nickel ores in the Sudbury district has been known for a good many years—almost as long as the ore deposits themselves—the Mond Nickel Company were the first to effect their recovery on a commercial scale.

The precious metals values of the different Sudbury ores vary considerably, and are generally higher in the copper-rich ores. These values are so very small that a direct determination in the ores gives quite unreliable results. This is not surprising if one considers that some of the ores contain only one unit of total precious metals in about two million units of ore, and that this one unit will consist of seven different metals, each with a different chemical behaviour. It is only after the ores have been smelted to a Bessemer matte containing about 80 per cent combined copper and nickel that the precious metals content can be determined with some degree of certainty. From the figures thus obtained, the precious metals content of the ores can be calculated, provided the tonnage of ore used to produce one ton of matte is known.

The recovery of these minute quantities of precious metals out of such a large amount of gangue and sulphides of iron, copper, and nickel seems at first glance a commercial and technical impossibility. Nevertheless, science has found a way to conquer all the difficulties, and quite substantial quantities of the precious metals contained in the Sudbury nickel-copper ores have been regularly recovered for many years by the Mond Nickel Company.

---

*The Mond Nickel Company, Limited.

For further particulars as to the precious metals content in the Sudbury ores, and in the mattes produced therefrom, the publications listed in the Appendix may be consulted.

In the earlier refining processes for treating the nickel-copper ores, processes which consisted chiefly in smelting operations only, the precious metals could not be recovered, as they were alloyed with the end-products of the process, *viz.*, the copper and nickel. Although part of the copper so produced was further refined by electrolysis, only a fraction of the precious metals contained in the ore was in this way recovered.

In the newer processes, the final refining of the copper and nickel takes place at such low temperatures that the precious metals cannot alloy with the copper and nickel, and are, therefore, left behind in a concentrated form in the refining residues.

Of the two concerns chiefly interested in the refining of the Sudbury nickel ores, the Mond Nickel Company adopted a low-temperature refining process 27 years ago, and the International Nickel Company are now also changing over to a process working under similar temperature conditions. The two processes are otherwise quite dissimilar, as a short description of both will show.

The International Nickel Company are now refining part of their nickel by means of electrolysis, and, according to published information, their practice is briefly as follows:

The ores are smelted and bessemerized, and the bulk of the copper contained in the ore is separated from the nickel by smelting the matte with salt-cake. The copper sulphide mixes with the salt-cake and its specific gravity is thereby so reduced that, on cooling, two separate layers are formed, the upper one being richer in copper and the lower one richer in nickel.

The enriched nickel matte is cast into anodes and subjected to electrolysis in a specially constructed cell. The precious metals contained in the matte are left behind as anodic sludge, from which they can be recovered in a similar way to that described further on.

The Mond Nickel Company's process, in operation at Clydach, near Swansea, S. Wales, for working up the matte produced at their smelter at Coniston, Ontario, is the well-known carbonyl process, discovered by the late Dr. Ludwig Mond and Dr. Carl Langer in the year 1889. Its main features are that finely divided metallic nickel is exposed to the action of carbon monoxide at ordinary temperatures, resulting in the formation of a volatile nickel compound, which is known as nickel carbonyl and which has the property of being readily decomposed into its constituents on heating to 200°—250°C. The carbon monoxide is regenerated and is used over and over again as the vehicle to carry nickel from one vessel to another. The nickel recovered from this volatile compound is of exceptional purity, as no other known metal forms a volatile compound with carbon monoxide with the same ease under normal working conditions. The principal operations in carrying out the process are as follows:

(1). Smelting of the ores into a matte and bessemerizing the same to remove the iron and gangue. This operation concentrates, about 20 times, the precious metals contained in the ores.

(2). Grinding and calcining the matte so that the sulphides are converted into oxides.

(3). Copper extraction. The calcined matte is treated with dilute sulphuric acid, which dissolves the bulk of the copper. The copper sulphate is crystallized out of the hot solutions and marketed as such.

(4). Reduction to metals. The copper-extracted matte is reduced to a metallic state by means of water gas at a temperature of about 300°C.

(5). Volatilization of nickel. The reduced matte is exposed to the action of carbon monoxide, which combines with the nickel forming a very volatile carbonyl, which is carried away in the constantly flowing stream of carbon monoxide into the decomposers.

(6). Decomposition. On passing the escaping gases from the volatilizers through vessels filled with nickel pellets, which are kept in slow motion at a temperature of 200°-250°C., the carbonyl decomposes, the nickel settles out in a solid layer on the nickel pellets, which in consequence grow continuously in size, and the carbon monoxide is returned to the volatilizers to take up a fresh lot of nickel.

(7). The residues from these operations contain practically the whole of the original precious metals, and the concentration at this stage is about 1,600 units of ore to 1 of residues. They still contain some copper and nickel, and to remove these as far as possible they are treated with sulphuric acid and washed free of the salts formed.

After this treatment, the residues are ready for the precious metals refinery, and represent a concentration of about 16,000 units of ore to one unit of residues. At this stage of concentration, an analysis gave the following figures:

	Per cent	Oz. per ton of 2,000 lb.
Platinum	1.85	540
Palladium	1.91	557
Gold	.56	163
Iridium, rhodium, ruthenium	.39	113
Silver	15.42	4,500

The relative proportion in which the iridium, rhodium, and ruthenium are present was determined, and it was found that one hundred parts of this mixture contained 10 parts iridium, 50 parts rhodium, and 40 parts ruthenium.

PRECIOUS METALS REFINING PROCESS

After careful laboratory research, it was considered that, provided the lead content of the precious metals concentrate was kept within reasonable limits, say below 10 per cent, it would be possible to extract and purify the platinum, palladium, gold and silver by direct acid attack and wet-process treatment, and to avoid bulk smelting operations, excepting the reduction of silver chloride by smelting. However, it was found that the direct acid attack upon the precious metals concentrate led to immediate difficulties in the process. The chemical reactions of the precious metals which gave high extractions and yielded products of reasonable purity in the laboratory, gave only partial extractions and yielded products of relatively low purity when operations were conducted on the process scale.

In addition to the contamination of the precious metals precipitates by salts of the base metals, necessitating repeated re-treatment of the precipitates, there arose the still more complex problem of treating the bulky hydroxide and oxychloride precipitates and reduction residue slimes containing antimony, lead, nickel, copper, arsenic, sulphur, selenium, and tellurium, as well as their quota of one or all of the precious metals.

By experimenting on process scale, it was found that the most satisfactory way of separating these base-metal precipitates and residues, was by resorting, firstly, to calcination to remove the sulphur group, and secondly, to smelting with litharge and alkaline fluxes in a reducing atmosphere to remove base metals with the slag, and to obtain a silver-rich lead bullion in ingot form.

By partial cupellation of the silver-rich lead bullion, if necessary with the addition of further silver to give a ratio of 6 silver to 1 of other precious metals, a silver bullion was obtained.

By electrolysis of the silver bullion, using a silver nitrate electrolyte, adjusting conditions so as to minimize contamination of the bath and of the kathodic silver by palladium, pure silver was produced, and an anodic sludge was obtained containing platinum, palladium, gold, rhodium, ruthenium and iridium, in a state of fine division. The platinum, palladium, and gold in the anodic sludge were thus readily able to be extracted by aqua regia, and to be separated and purified by known precious metals reactions.

The separation of the platinum, palladium, gold, and silver from the contaminated intermediate products was thus accomplished.

From the fact that it was imperative to resort to furnace treatment to resolve the platinum, palladium, gold, and silver contents of the intermediate products contaminated with base metals, the question arose whether these base metals could be economically eliminated from the precious metals concentrate by smelting. This proved to be possible, and after design and trial of suitable furnace plant, smelting of the concentrate became standard practice.

The wet-process treatment of the silver grain consists in parting the silver with sulphuric acid, silver and some palladium going into solution and being recovered as silver chloride and palladosammine chloride, $Pd(NH_3)_2Cl_2$.

The insoluble from the silver parting, containing the platinum, gold, rhodium, ruthenium, iridium and balance of palladium, is treated with aqua regia, the platinum, gold, palladium, and some rhodium going into solution.

Subsequent operations depend upon the proportions in which the precious metals are present in solution. Platinum is precipitated as platinichloride; gold as such.

The platinum and palladium salts are re-treated and finally ignited to yield the pure metals.

The silver chloride is reduced, and the silver given an electrolytic purification.

The gold is also given an electrolytic purification.

The insolubles from the aqua regia treatment are worked up into a rhodium-ruthenium-iridium concentrate for treatment in the laboratory.

In general, the reactions of the rhodium-ruthenium-iridium metals are less positive than the reactions of the other platinum metals, and their extraction and separation involves a complex series of operations calling for a high degree of skill, patience, and perseverance.

The average purity of the precious metals recovered is noteworthy:

	Pt	Pd	Au	Ag	Rh	Ru	Ir
Per cent.....	99.92	99.91	99.97	99.94	99.65	99.21	99.80

A minimum recovery of 95 per cent of precious metals in the concentrates is obtained.

APPENDIX

LIST OF REFERENCES

1. The Annual Reports of the Department of Mines, Ottawa, on the Mineral Production of Ontario.

2. The Origin, Geological Relations, and Composition of the Nickel and Copper Deposits of the Sudbury Mining District, Ontario, Canada, by A. E. Barlow. Geol. Survey of Canada, Vol. XIV, 1904.

3. The Nickel Industry, by A. P. Coleman. Mines Branch, Dept. of Mines, Canada, Bull. No. 170, 1913.

4. Genesis of the Sudbury Nickel-Copper Ores as indicated by recent explorations, by H. M. Roberts and R. D. Longyear. Trans. Can. Inst. Min. Met., Vol. XXI, 1918, pp. 80-126.

5. The Platinum Situation in Canada, by J. J. O'Neill. Geol. Survey of Canada, Summary Report, 1918, Pt. G., pp. 1-19.

6. Nickel Ores, by W. G. Rumbold. Imperial Institute Monograph on Mineral Resources, with special reference to the British Empire. 1920.

7. The Platinum Metals, by A. D. Lumb. Imperial Institute Monograph on Mineral Resources, with special reference to the British Empire. 1920.

8. Le Platine et les Platinifères de l'Oural et du Monde. Geneva; Soc. anon. des éditions (Sonor.). 1921.

9. The Mineral Industry of the British Empire and Foreign Countries, 1919-1921: Platinum and Allied Metals. H. M. S. O., London, 1922.

10. Recovery of Precious Metals from Sudbury Ores, by R. L. Peek. Trans. Can. Inst. Min. Met., Vol. XXV, 1922, pp. 122-135.

11. Review of Investigations of the Ore-dressing and Metallurgical Division. Mines Branch, Dept. of Mines, Canada, Summary Rpt. 1922; No. 605, pp. 71-193 (1924).

12. The Mineral Industry during 1925. Article by G. A. Roush. Vol. 34, 1926. (McGraw-Hill Book Company).

13. Investigation of the Structure of Native Platinum. Zeits. f. Anorg. Chem., 1926, Vol. 159, pp. 99-142.

14. The Mineral Production of Ontario in 1926. Dept. of Mines, Ontario. Bull. No. 60, 1927.

DISCUSSION

MR. J. DAWSON (Canada): Mr. Chairman, there seems to be some doubt regarding the occurrence of platinum in the lead-zinc-copper ore-bodies now being exploited near Sudbury. I have seen statements both ways. Can you give us any information on the subject?

THE CHAIRMAN (DR. A. P. COLEMAN): As Chairman, I think it would be much more desirable if some one from the audience should take up the subject.

MR. T. W. GIBSON (Canada): I am not able to throw any light upon the enquiry proposed by Mr. Dawson. I have nothing to report from the Department of Mines on any platinum that has been discovered in these newly opened deposits.

But with regard to platinum and allied metals, we have in the nickel and copper ore of the Sudbury region a very remarkable ore. It is not only valuable for the nickel and copper which it carries, but it also contains gold and silver, platinum, palladium, iridium, osmium, and ruthenium, and these rare metals are regularly recovered by the nickel companies.

The methods of refining for the copper and nickel ore are three in number: the wet, or chemical method, ordinarily known as the Orford method; the electrolytic method; and the Mond method. The two last, the Mond and the electrolytic methods, lend themselves much more readily to the recovery of these rare and precious metals than the Orford method, the one employed by the largest of the companies, the International Nickel Company. Recently a change has been made by that Company in their methods of recovery, and now much larger proportions of these rare elements are recovered by the International.

I think Canada, largely through the recoveries from the Sudbury ores, is now the third largest producer in the world of platinum and the platinum group of metals. Russia, and Colombia in South America, take first and second places.

The presence of these metals in the Sudbury ores is a source of very considerable profit, and we are now told that they are found in considerably larger proportions in the copper deposit that has recently been discovered at depth in the Frood mine, which is likely to be opened up in a short time and will become a very important producer of copper.

The nickel, of course, up to the present time has been the leading product of the Sudbury district. The copper follows in order, then the gold and silver and rare metals which I have mentioned.

You will find a comprehensive history of the nickel industry in this country, with much information about the deposits of nickel in other parts of the world, contained in the report of the Royal Ontario Nickel Commission, a Commission appointed during the war by the Ontario Government to investigate the whole subject of nickel, which was of so much importance at the time. If you are interested in the subject of nickel, I would suggest that you consult that report, which was published in 1917. Some copies are still left of a large edition, and may be obtained from the Department of Mines of the Ontario Government.

PROFESSOR G. H. STANLEY (Johannesburg): The subject of this paper is one of great interest to South Africa at the present time. Probably all of you know that platinum has been discovered there in rocks of two distinct types: one is felsite, in which the platinum occurs as metallic particles; the other, and as is now demonstrated, much the more important, is a basic rock in which the precious metal occurs mainly with copper and nickel sulphides which, when concentrated, have very much the same composition as the massive ores of Sudbury. The recovery of nickel and copper and platinum from that concentrate will, I think, follow eventually very much the same lines it has here in Canada and in South Wales.

The position of South Africa in this respect is likely to be unique in the future. It is already so in two or three different ways. A recovery of metallic platinum has been made there, on a scale which, I believe, is unique from massive rock—that is, from dunite at Onverwacht. There are one or two other points of unique interest. The mineral sperrylite, which was discovered, I believe, to be the chief source of platinum in the Sudbury ore, has been found in the Transvaal in larger crystals than anywhere else in the world.

There is, further, a hitherto unknown mineral of palladium, which has recently been discovered in the Transvaal, a compound of palladium and antimony. These few facts, I think, point to the strong probability of further developments in the future. Quite a lot of interesting factors on platinum will come from Africa, at least we hope so. I feel very much indebted to the authors of this paper for the valuable information they have given us concerning the methods of recovering these precious metals.

MR. F. WARTENWEILER (South Africa): Speaking as a metallurgist, and being associated with the recovery of platinum, in the Transvaal, it may interest this Congress to listen to my brief description of the methods which are in use at present on what we class as the dunite ore. The metal is found in the metallic form, alloyed with iron in the neighbourhood of twelve per cent, the platinum content of the alloy being in the neighbourhood of eighty-four per cent. The balance of the platinum-group metals present are osmiridium, palladium, and rhodium.

This metallic platinum is found in the form of grains, somewhat crystalline, and flakes. Occasionally fairly large pieces are found; I have seen particles the size of a pea. That is rather unusual, and on the whole the metal is in a fine state of division. The recovery is by means of gravity concentration and the percentage of recovery is in the neighbourhood of eighty-six per cent on a 9.0 dwt. ore. This relatively high percentage by gravity concentration will indicate to you that the platinoid metal is in a clean form and not associated with gangue minerals. There are no sulphides in this particular dunite. I am speaking of the Onverwacht deposit in the Lydenburg district.

The concentrate from the gravity method of concentration is amalgamated and the subsequent product contains seventy-four to seventy-nine per cent platinum-group metals. This is shipped and refined abroad.

There is another deposit of dunite ore which is being worked and which is also concentrated by gravity. As regards the norite sulphide ores, to which Professor Stanley has alluded, the matter of treatment is in the research and development stage. As these ores are more refractory, considerable time will be required to work out the problems in connection therewith.

SIR ALBERT E. KITSON (Gold Coast): I should like to add a few words to the discussion because, in the Gold Coast of West Africa, we have by assay found platinum in hornblendite dykes, and also associated with vein-quartz in a decayed basic rock. The assays give low values, from 3 to 6 grains per ton, and smaller ones of copper and nickel. The local conditions are such that panning tests are indeterminate as to the presence of granular metallic platinum. These are two different types of occurrence apparently, just as in South Africa. There are many dykes of ultra-basic and basic rocks through the Gold Coast and other parts of West Africa which may reveal something of special importance.

In addition to that, platinum occurs in norite in Sierra Leone, where it was discovered recently by Major Junner, M.C., the Director of the new Geological Survey of that Colony. He found the platinum by panning the gravels of streams flowing over an area of norite. Here, may I emphasize the importance of panning in ordinary prospecting, for, in my opinion, there is not sufficient recognition by geologists of the frequent use of this method. So far as preliminary investigations have gone there seems to be a general resemblance between the occurrences of platinum in Sierra Leone and at Sudbury.

DR. J. A. L. HENDERSON (Canada): I want to ask Professor Stanley whether he has any knowledge of the presence of platinum—as has been reported—in the well-known auriferous nickel-cobalt veins which occur in the Middleberg district in the Transvaal.

PROFESSOR STANLEY: I am sorry, but I haven't any information on that particular point.

THE CHAIRMAN: I think, perhaps, there is one point that should be mentioned regarding the occurrence of the platinum-group metals at Sudbury. We find that palladium is present in considerable amount as compared with platinum. The latter we know occurs as the arsenide, sperrylite, but no compound of palladium has yet been found. That is a curious fact, and it is very interesting to find that such a compound occurs in the South African deposits.

MR. O. N. SCOTT (Canada): There is another occurrence of platinum in Canada, in the gravels of the Tulameen river in southern British Columbia, where small amounts of platinum have been recovered by panning.

THE CHAIRMAN: The platinum in British Columbia is native platinum and has apparently come from serpentine rocks, in the same way as in Siberia and other places where platinum placers occur.

MR. DAWSON: I may mention that platinum has been found in another part of Ontario, in the northwestern part of the Province, where nickel and copper ores associated with serpentine rocks are reported to be quite rich, comparatively speaking of course, in platinum and palladium and other metals of that group.

NOTES ON THE OPERATION OF THE REDUCTION PLANT AT WEST SPRINGS, LTD.*

BY CARL R. DAVIS†, J. L. WILLEY‡, AND S. E. T. EWING||

(Members, S. Af. Inst. Eng.)

(Winnipeg, Man., Meeting, September 3rd, 1927)

In a paper read before the American Institute of Mining and Metallurgical Engineers in February of this year, and read at a meeting of this Institution on the 15th of April, 1925, the authors endeavoured to give a résumé of the experimental work leading up to the design of the extensions to the reduction plant at Springs Mines, Ltd., and the new plant at West Springs, Ltd. In the present paper it is intended to give a review of the technical results and corresponding costs actually obtained at West Springs, Ltd.

The plant was started-up in April, 1924, and went into full commission the following month without any difficulties being encountered. After a few months' operation, it became clear that the eight tube mills installed were capable of handling 40,000 tons per month, and actually in the month of December the plant milled 41,050 tons. In view, however, of possibilities in respect of tonnage production, two additional tube mills were installed, the first of which went into operation on the 5th of January and the second on the 19th of January of this year, thus bringing the nominal capacity of the reduction plant up to 50,000 tons. When this figure is actually reached, a corresponding improvement in the costs, as detailed below, may be anticipated.

---

*This paper was published in the Journal of the S. Af. Inst. Eng., XXIII, No. 11, 1925.

†Consulting Engineer, Anglo-American Corporation of South Africa, Ltd., Johannesburg.

‡Consulting Metallurgical Engineer, Anglo-Amer. Corp. of S. Af., Ltd., Johannesburg.

||Consulting Mechanical and Electrical Engineer, Anglo-Amer. Corp. of S. Af., Ltd., Johannesburg.

COSTS

The month of January of this year marked the introduction of a new system of statistical records on the mines controlled by the Anglo-American Corporation of S.A., Ltd., and as the new system makes many details of working costs more readily accessible, the period covered by the three months January, February and March of this year has been dealt with for the purpose of this paper.

For the period under review, the general operations were as follows:

Tons hoisted from the mine	157,589
Tons from development dump	10,105
Making a total tonnage sent to the sorting and crushing station	167,694
Of which was eliminated by sorting (tons)	32,304
Tons milled	134,400
Tons treated	135,861
Average reduction cost per ton milled over the period	3s. 6.480d.

The above total reduction cost is made up under the following main heads, each figure being the average for the period:

Sorting and crushing	7.0481	pence
Tube milling	20.6535	"
Cyaniding slime	8.4518	"
Butters' filter plant	3.3320	"
Recovery:		
Precipitation	1.9571	"
Smelting and osmiridium recovery	1.0375	"
Total	42.4800	"

Sorting and Crushing

This section begins with the transport of ore from the headgear bins, includes the elevation of rock to and withdrawal from the stock pile, and ends with the delivery of the ore into the main tube mill bins, embracing also the delivery of ore from the development rock dump, the disposal of all waste rock and the operation of the washing plant.

The detailed costs of this section are made up as follows:

	Cost per ton milled. d.	Cost per ton handled. d.
White wages	.4911	.3946
Native wages	2.1071	1.6931
Crusher spares	.6661	.5352
Conveyor belt suspense account	.5357	.4305
Oil and grease	.1446	.1162
Sundries and phthisis charges	.1500	.1205
Workshops	.4821	.3874
Power	.3714	.2984
Dump account	.7982	.6414
Washing plant	1.3018	1.0460
Totals	7.0481	5.6633

Tube Milling

This section begins where the previous section ends, and includes the milling and classification of tube mill pulp and delivery of same to the main pulp elevating pumps; also transport, sorting and crushing of reject pebbles.

The detailed costs of this section are made up as follows:

	Cost per ton milled. d.
White wages	1.0464
Native wages	.9250
Liners suspense account	1.0714
Tube mill spares, castings, etc	1.7928
Conveyor belts	.2179
Sundry stores	.1357
Oil and grease, etc	.3536
Lime	.2286
Electrical material	.0571
Sundries	.3750
Workshops	1.3696
Electric power	10.1821
Air power	.2983
Assaying	.1429
Return solution service	.1321
Dorr classification and tube mill circuit pulp elevation	.8750
Reject pebble transport, sorting and crushing	1.4500
Total	20.6535

The drawing (Figure 1) shows this portion of the plant in diagrammatic form. The drawing is, of course, not to scale, but shows the main features of the plant coming under the foregoing two sections. These sections in effect cover the reduction of the ore to finished pulp.

Cyaniding Slime

This process begins with the main pulp pumps, and includes slime collection, decantation, hosing, transfer to Pachuca agitating tanks and main pumps to stock pulp tank, also disposal of tailings and maintenace of slime dams.

The detailed costs of this section are made up as follows:

	Cost per ton milled.	Cost per ton treated.
	d.	d.
White wages	.8196	.8108
Native wages	.3929	.3886
Cyanide	2.9375	2.9059
Chemicals and assaying	.0321	.0318
Lime	.5769	.5707
Lead acetate	.2392	.2367
Pump spares, etc.	.3071	.3038
Sundries	.2232	.2208
Workshops	.1232	.1219
Electric power	.3305	.3269
Return solution service	.1321	.1307
Main pulp pumps	.3929	.3886
Air agitation	.2071	.2049
Rand Water Board charges	1.7375	1.7188
Totals	8.4518	8.3609

Butters Filter Plant

This section begins at the delivery into the stock pulp tank and ends with the tailings discharge pumps.

The detailed costs of this section are made up as follows:

	Cost per ton milled. d.	Cost per ton treated. d.
White wages	.8696	.8602
Native wages	.3661	.3621
Chemicals and acids	.2393	.2368
Pump spares and castings	.1964	.1943
Oil and grease	.0696	.0689
Sundries	.2429	.2402
Workshops	.1571	.1555
Electric power	.9821	.9716
Air agitation	.0696	.0689
Assaying	.1393	.1378
Totals	3.3320	3.2963

Precipitation

This section begins at the solution clarifying tanks, embraces the Crowe-Merril zinc-dust precipitation and ends with the barren solution pumps.

The detailed costs of this section are made up as follows:

	Cost per ton milled. d.	Cost per ton of solution precipitated. d.
White wages	.4196	.2308
Native wages	.0660	.0363
Zinc dust	.4964	.2730
Filter cloth and paper	.2250	.1237
Chemicals and lead acetate	.2661	.1463
Sundries	.1268	.0697
Workshops	.0750	.0412
Electric power	.2232	.1227
Assaying	.0590	.0324
Totals	1.9571	1.0761

Tons of solution precipitated = 244,418

Smelting and Osmiridium Recovery

This section begins with the handling of gold zinc slime from Merrill presses, covers all other operations up to depositing the gold with the refinery authorities, and includes recovery of osmiridium.

The detailed costs of this section are made up as follows:

	Cost per ton milled. d.	Cost per fine oz. smelted. d.
White wages	.2500	.6440
Native wages	.0286	.0736
Sulphuric acid	.1375	.3542
Pots and liners	.2054	.5290
Chemicals	.1160	.2990
Coal	.1000	.2576
Sundries	.1339	.3450
Workshops	.0429	.1104
Assaying and electric power	.0232	.0598
Totals	1.0375	2.6726

Figure 2 shows the portion of the plant covered by the latter four sections in similar diagrammatic form. These sections deal with the recovery of gold from the mill pulp.

The eight sub-accounts necessary for the building up of these costs are also reproduced in order to make the costing details as complete as possible, and are as follows:

Washing Plant

Tons milled	134,400
Cost per ton milled	1.3018d.

	Cost per ton milled. d.
White wages	.1375
Native wages	.3696
Conveyor spares, castings, etc.	.2036
Lime	.0679
Sundries	.0929
Workshops	.2588
Electric power	.0465
Rand Water Board—water	.1250
Total	1.3018

Main Haulage Dump

Tons waste sorted	32,304
Ton reclaimed	10,105
Tons waste from mine	6,650
Total tons handled	49,059
Cost per ton handled	3.1945d.

	Cost per ton handled. d.
White wages	.3229
Native wages	2.1526
Oil and grease	.1076
Sundries	.2299
Workshops	.2250
Power	.1565
Total	3.1945

Reject Pebbles

Tons transported	33,677
Tons sorted	2,136
Tons crushed by disc crushers	31,541
Tons milled	134,400

	Cost per ton milled. d.	Cost per ton crushed by disc crushers d.
White wages	.0321	.1369
Native wages	.5376	2.2904
Crusher spares	.4554	1.9403
Conveyor spares	.0821	3500
Sundries	.0411	.1750
Workshops	.2071	.8827
Electric power	.0946	.4033
Totals	1.4500	6.1786

Dorr Classification and Tube Mill Circuit Pulp Elevation

	Cost per ton milled. d.
White wages	.1964
Castings	.0393
Sundries	.0393
Workshops	.0732
Electric power	.5268
Total	.8750

Main Pulp Pump

Cost per ton milled	.3929d.

Return Solution Service

Cost per ton milled	.2642d.

Air Agitation

Cost per ton milled	.3482d.

Assaying

Cost per ton milled	1.175d.

All the foregoing figures are taken from the mine accounts, which are framed in the form given.

In connection with the foregoing costs, we would draw attention to one or two items of expenditure which are somewhat unusual, *viz*:

Rand Water Board Water.—It will be seen that the cost of water charged to the plant amounts to 1.8625d. per ton milled. This arises from the fact that the mine has extremely limited sources of water at its own disposal.

Compressed Air for Pulp Agitation is supplied by a separate plant which is a direct charge to reduction costs. A certain amount of compressed air is also used for other services, such as air lifts for floor drainage. The amount of air so used is metered and debited at cost of production. In the same way, all repair work which is not carried out as a direct charge against the reduction plant, is debited at current workshops cost. Native labour is charged at the current mine rate.

Suspense Accounts.—It may also be noted that certain items of material, *viz.*, tube-mill liners, conveyor belting, etc., are dealt with on a fixed basis per month, in other words, by means of suspense accounts. The amounts of these are calculated to meet safely the average annual expenditure on such items, and are considered to be on a very conservative basis.

Running Time.—During the period under review, the tube mill plant ran for 97.135 per cent of the possible running time (*i.e.*, 144 hours per week). Ordinary stoppages accounted for 2.095 per cent of the time lost, and the remaining .770 per cent is accounted for by failure of the main power supply.

Running Staff.—The number of white men employed on the reduction plant is twenty-five, which figure includes three sectional managers, one clerk, one grader and four mechanics.

Power Consumption.—During the period under review, the consumption of electricity amounted to 27.04 k.w.h. per ton milled, corresponding to a cost of 12.308d. per ton milled. The consumption of the electrically driven air compressors for slime agitation is, of course, included in the foregoing. Power for tube milling alone amounted to 2,708,019 k.w.h. The grading of the final product was

+60	+90	+200	−200
Nil	3.30%	23.37%	73.33%

so that 96.7 per cent of 134,400 tons of –90-mesh was produced for this figure, or 20.83 k.w.h. per ton of –90-mesh produced.

GENERAL NOTES ON OPERATION

Fine Grinding.—Perhaps the most essential feature of the West Springs plant is that it was designed with the express intention of grinding the whole of the ore to a considerably greater degree of fineness than that common to ordinary Rand practice, particularly on the Central Rand where, owing to the nature of the ore and type of existing plants, such a degree of fine grinding is not economically desirable. Members of the Institution are fully aware that fine grinding is apt to be a costly process, and that as the degree of fineness of the finished product increases, so, normally, do the amount of power and plant required to perform the operations tend to increase on a rapidly rising scale. It is, of course, perfectly possible to grind to almost any desired degree of fineness by means of stamp milling only, and, with a greater degree of economy, by means of stamp-milling-cum-tube-milling. The production of a pulp of approximately the same degree of fineness as that for which the West Springs plant is designed has, of course, actually been attained in one or two instances by plants of standard type, but the conditions have been abnormal in these cases, inasmuch as the capacity of the reduction plants have been, owing to extraneous causes, very considerably in excess of the monthly tonnages available for milling.

The authors' experience in this connection may be summarized as follows:

> In December, 1923, and January, 1924, a two months' test was carried out on the original stamp-mill-tube-mill plant at Springs Mines, Ltd. This test consisted in producing a pulp of the same average grading as that being produced in the new so-called 'all sliming' section of the plant. Over the period of two months, a product of similar grading, resulting in a similar residue value, was produced in the two sections. At the end of the period a careful comparison of the costs on the original plant when producing this finer product, with the costs during the preceding four months, when the normal grading of
>
> | +60 | +90 | −90 |
> |---|---|---|
> | 0.5 to 1% | 8 to 10% | 90 to 92% |
>
> was being produced, showed an increase in the cost of stamp milling and tube milling of 6.061d. per ton milled.

The costs now put forward will probably compare favourably with those pertaining to the older type of plant, in spite of the considerably increased fineness of grinding. As detailed in the author's last paper, the capital cost involved is considerably less.

SORTING AND CRUSHING PLANT

As the milling process is carried out in cyanide solution, it was decided that a thorough preliminary alkaline wash would be very desirable, and advantage was taken of this to make the washing process as complete as possible in order to minimise wear and tear of conveyor belts.

A year's experience of conveyor maintenance has more than confirmed our view that good washing is essential in order to obtain a good belt life. In the washing process over the period under review, 1,340 tons of slime, with a grading analysis of $\frac{+200}{2\%}$ $\frac{-200}{98\%}$ were eliminated and pumped direct to the slime plant for treatment. This quantity represents 1 per cent of the total ore milled.

Belt Conveyors.—The type of automatic feeder employed on the 36-inch belt feeding run of mine ore to the stock pile, and the 36-inch conveyor feeding the sorting and crushing plant, has given exceedingly good results owing to the careful design of the chute angles and the speed of delivery in relation to the belt speed. These belts to date have each carried 585,000 tons of run of mine ore and show so few signs of wear and tear that, barring accidents, their life should be about three years. Throughout the conveyor plant, as far as possible, incoming ore is cushioned on a bed of fines. The mechanical feeders provide this cushion automatically. As the total feed to the tube mill bins is practically all minus 1¾-inch material, and has been thoroughly washed, it was decided to make use of an automatic tripper for feeding the tube mill bins instead of the more common present-day method, *viz.*, a shuttle belt. No difficulties of any kind have attended the use of the tripper. There appears to be a considerable saving in labour cost, and a good mixture of the ore in the bins is easily secured. The latter is rather an important point in a plant of this nature.

The sorting and crushing plant is fed by a single automatic feeder by which the hourly rate of flow of run of mine ore into the plant can be closely regulated. The authors consider that a steady flow of ore is a very important factor in the general capacity and efficiency of a sorting and crushing plant. A complete warning bell system, with pushes at all strategic points, together with a push-button control system operating on the no-volt release of the driving motors, enables the main feeder or any of the belts to be stopped instantaneously from a number of points in case of accident, choking of chutes or other eventualities. This arrangement has in many instances prevented damage to belts and gear, and has already saved its initial cost several times over.

Crushing.—Crushing is carried out by two gyratory crushers of standard type, fed from steady-head bins containing about an hour's supply of ore per crusher. This enables a continuous choke feed to be maintained which greatly improves the product from the crushers, and the steady-head bins minimise the effect of temporary stoppages in the flow of ore through the plant. The sorted waste bins are of large capacity, the bottom of the bin being formed by waste rock inside the angle of repose resting on the solid ground. The sorting belt floor is hung from the roof principals instead of by posts going down through the waste bins. This design is, of course, not novel, but is excellent in that it reduces the maintenance of bin linings to a minimum.

Tube Milling Plant.—In the opinion of the authors, the back-to-back arrangement of plant lends itself to easy and, therefore, good supervision. Furthermore, ample space and really good daylight are required in a lay-out of tube mills and Dorr classifiers. The ordinary double-sided bin commonly used in back-to-back stamp mill practice, does not permit of these conditions being satisfactorily attained. The type of bin actually adopted ensures ample light at the head or feed end of the tube mills, and permits the tubes on opposite sides of the building to be staggered on 30-ft. centres, thus giving ample space and daylight, at the same time allowing the bins to be self-emptying. The ordinary type of belt drive for tube mills has been discarded in favour of enclosed single reduction gears, the gear boxes being fitted with 'Michell' bearings and automatic lubrication throughout. The wear and tear of these gears is inappreciable after twelve months' service, and points to a long life. They have resulted in great saving in maintenance cost, and there is no doubt a considerable increase in mechanical efficiency. What is probably more important is that, with the adoption of these gears, all difficulties in connection with starting tube mills, which have been standing for some hours, have disappeared. In a plant which is shut down for twenty-four hours every week, the aggregate loss of time in starting-up tube mills is appreciable, and this point is particularly mentioned because it is apt to be lost sight of.

In a closed tube-mill-Dorr-classifier circuit, it is necessary to introduce some device for elevating either pulp from the tube mill outlet to the classifier, or the classifier oversize to the tube mill. The ordinary scoop method for elevating the latter product into the tube mill was found impracticable owing to the size of the tube mill and classifier units used. Recourse was, therefore, had to supplying the necessary solution, required for classification, under pressure to a hydraulic jet, and thereby elevating the tube mill effluent to the classifiers. This method is by no means perfect. The mechanical efficiency of the process is probably not more than 8 per cent, as refinements in the form of jet to attain better efficiency mainly result in increased maintenance costs. On the other hand the device is extremely simple and effective in operation, and automatically maintains the correct ratio of dilution, which is very necessary for consistent classification.

It may be of interest at this point to state that the Dorr classifiers, which are 8 ft. wide and 18 ft. 4 in. long, are operated at 13 strokes per minute. The average grading of the finished product of the overflow of the classifier is

+60	+90	+200	−200
Nil	3.30%	23.37%	73.33%

and the average grading of the oversize return to the tube mill:

+60	+90	+200	−200
39.2%	33.3%	21.1%	6.4%

the ratio of dilution in the classifier overflow being seven of solution to one of solids.

The quantity of selected grinding pebble added to the tube mills averages 27 tons per tube mill per 24 hours. This quantity is about 7 tons higher than that anticipated as the result of experimental work on the same size of tube mill carried out at Springs Mines, Ltd. The difference is attributable to a lack of sufficient pebbles of really suitable shape and size, which deficiency has to be made up by the addition of pebble of a slabby and, therefore, more easily fractured form.

On the subject of tube mill liners, the authors stated in their last paper that they had hopes that certain types of liner then being experimented with would materially increase the output per tube. While the experimental work carried out in this connection was by no means final and conclusive, results obtained on the whole seemed to show that within the very narrow limits of grading imposed by the necessity of obtaining a specified residue from the ore treated, no particular advantage pertained to these liners over that obtainable with the ordinary Osborn bar type. It must be borne in mind, however, that with a wider range of grading, results might have been quite different. Members will be aware that once a reduction plant has gone into commission, the possibilities of anything like broad experiment are almost non-existent. A point worth mentioning is that the increased diameter of the tube mills does, in the author's opinion, somewhat increase the difficulty of securely wedging the ordinary Osborn bar lining. A modification of the ordinary procedure has, however, been adopted which quite overcomes this difficulty; it consists mainly in a special locking ring in the middle of the length of the tube mill.

The amount of reject pebble to be handled in this plant is considerably in excess of that handled in ordinary practice. The total figure, for the period under review, is 33,677 tons. The handling of these pebbles is entirely automatic, and they are delivered by belt to the reject pebble sorting and crushing plant. The reject material is composed of approximately 50 per cent reef and 50 per cent waste. The sorting of pebbles from 1-in. to 1½-in. diameter is, of course, an expensive process per ton sorted, which is reflected in the cost of native labour given above under this head, but it must be borne in mind that every ton eliminated at this point bears no further cost of cracking, tube milling and treatment, and also makes room for a ton of new ore of the average grade of ore milled. The pebbles are cracked in disc crushers, the object being not so much to obtain a fine product as to obtain fresh angles for attrition in the tube mill. It is, of course, very important to keep tramp iron out of crushers of this type, and this has been attained by a simple magnetic device.

The average grading of this material after cracking is as follows:

+1″	+½″	+¼″	+60	+90	+200	−200
Nil	6.2%	28.1%	60.1%	1.9%	1.2%	2.5%

Cyaniding Slime.—The finished product from the tube mill plant is elevated to six slime collectors 70 ft. diameter by 12 ft. high, with 5 ft. 6 in. coned bottoms. The solution overflows into internal peripheral launders and gravitates to storage tanks for return to the tube mill circuit, a sufficient quantity being withdrawn daily and sent to the precipitation plant to maintain the mill circuit at a figure of approximately 2.5 dwt. per ton of solution. In order to minimise the amount of pumping required for decantation of the remaining solution in the collectors, the tanks are interconnected by means of 8-inch pipes placed about half-way up the sides. The settled slime is transferred to Pachuca air agitating tanks in the usual way, except that separate pipe lines are provided for filling and emptying these tanks. This is done to reduce the amount of contamination of treated pulp to a minimum. This arrangement also shortens the cycle time of operation. The grading of the final product from the tube mill plant being somewhat coarser than that usually dealt with in ordinary slime and Butters filter plants, the grade of all piping carrying the final product is correspondingly increased.

The average time of agitation is 12 hours.

Butters Filter Plant.—This consists of sixteen hoppers containing 448 leaves; the average time taken per complete cycle is under 100 minutes, made up as follows:

Filling	8 minutes.
Taking on cake	12 to 15 minutes.
Emptying excess pulp	6 minutes.
Filling with solution	6 minutes.
Washing	35 minutes.
Sampling and dropping cakes	10 minutes.
Emptying excess solution	10 minutes.
Discharging to residue pit	5 minutes.

The thickness of cake varies from 1½-inch to 1¾-inch. The time required for hosing out the residue pit and pumping to the dam varies from 45 minutes to 60 minutes. The average charge treated per cycle is 220 tons.

Recovery.—Precipitation is carried out by the Crowe-Merrill zinc dust process in three 40-frame, 54-inch filter presses. The average quantity of solution precipitated is 64 tons per press per hour, two presses being normally in operation. Presses are cleaned up twice per month and, after acid treatment and calcination, the gold slime is smelted in a reverberatory pot furnace. The slime after acid treatment averages 35 per cent gold, and after calcination 60 per cent.

Owing to the extreme difficulty in prognosticating the extent and values of the occurrence of metals of the platinum group on these fields, it was not considered advisable to instal an elaborate plant for the sole purpose of increasing the recovery of these metals. This view was strengthened by experimental work carried out at Springs Mines in the latter part of 1923, which showed that an appreciable amount of osmiridium was locked up in the tube mills, and this could be recovered by a simple process of treatment of the tube mill concentrates. In the year 1924, at Springs Mines, Ltd., this method yielded 260 oz. of osmiridium concentrates from a total of 770,000 tons milled, at a quite inappreciable cost of recovery, and during the three months under review West Springs actually recovered 17.5 oz. from current milling operations.

General.—The following figures of working results obtained in the treatment plant for the period under review may be of interest:

Tons treated	135,861			
Average residue grading	+60	+90	+200	−200
	Nil	3.50	21.97	74.53
Average value of residue	.464 dwt.			
Average value of undissolved gold in residue	.422 dwt.			

Consumption of Stores

Cyanide	.309 lb.	100% NaCN per ton treated.
Zinc	.076 lb.	per ton treated.
Lime	2.458 lb.	" " "
Sulphuric acid	.072 lb.	" " "
Hydrochloric acid	.093 lb.	" " "
Lead acetate	.038 lb.	" " "

The grading results given throughout, with the exception of those for the disc crusher product, are obtained from the use of Locker's standard screens of the following dimensions:

Apertures per linear inch.	Diameter of apertures. Inches.	Diameter of wire. Inches.
60	.010	.0048
90	.006	.0036
200	.003	.0020

It may be of interest to mention, in reference to the statement made at the commencement of this paper, where it was indicated that working costs would be reduced with an increase in the tonnage milled, that since the above notes were compiled the results for the month of April have been received, which show that the tonnage milled was at the rate of 50,000 tons for a 27-day working month, and that the total reduction costs amounted to 3s. 3.627d. per ton as compared with the figure of 3s. 6.480d. for the period covered by this paper.

In conclusion, the authors' thanks are due to the Chairman and Directors of the Board of West Springs, Ltd., for their permission to put forward the figures and results contained in the foregoing notes.

THE CONTACT PROCESS FOR THE MANUFACTURE OF SULPHURIC ACID FROM ZINC BLENDE ROASTER GASES

By Stanley Robson (*Member, Inst. Met.*)*

(Vancouver, B.C., Meeting, September 15th, 1927)

Introduction

Probably few processes in chemical technology have excited more interest over a long period than the various contact processes for acid manufacture. Coming into being on a manufacturing scale in the closing years of last century, almost 70 years after the first attempt by Peregrine Phillips of Bristol, they heralded the advent of a succession of catalytic processes which are today changing the whole order and arrangement of chemical manufacture.

The interesting sequence of events which led to the commercial success of the contact process have been many times described elsewhere, as also have the varied properties of fuming sulphuric acid, or 'oleum', which is the common product of this manufacture. Those who require information on these matters are referred to the various text-books on the manufacture of sulphuric acid and to the famous paper given by Knietsch before the German Chemical Society in 1901.

The present paper is devoted to a discussion of the manufacture of contact sulphuric acid from zinc blende roaster gases.

Briefly stated, it may be said that the general requirement of any modern contact system is a cool gas containing any percentage of sulphur gas above 2 per cent, where the predominant sulphur-bearing component is sulphur dioxide.

---

*General Works Superintendent, National Smelting Company, Limited, London, England.

This gas is completely purified until, in an industrial sense, the only components are sulphur dioxide, oxygen, and nitrogen. Water vapour is removed along with all the other impurities. The dried, purified gases are converted into sulphur-trioxide-bearing gases by the agency of some suitable catalyst, usually finely divided platinum. The thermal control of the process of oxidation is maintained by heat exchange vessels, and the application of external heat can be avoided in all cases where the sulphur dioxide content does not fall appreciably below 4 per cent. The product of the combustion in the contact chambers is passed into an absorption system where the sulphur trioxide is dissolved in strong sulphuric acid, forming fuming sulphuric acid, or oleum, which can be reduced to the strength of commercial sulphuric acid by the addition of water.

No nitre is required in this process, as is the case with Chamber, Schmiedel, or Tower plants.

The successful launching of the first commercial contact unit by the Badische Anilin & Soda Fabrik Company at their works in Ludwigshafen was hailed as a great triumph, and high hopes were entertained that this process would rapidly and completely supersede the chamber process. That this has not been the case is apparent today. Nevertheless, the development of the contact process in favoured areas has been remarkable, and its utilization for zinc blende gases is now well developed. Moreover, steady progress in the art of contact sulphuric acid manufacture has been made, and today, with the advantages conferred by modern scientific engineering appliances, the choice of a sulphuric acid process for the utilization of blende roaster gases is one demanding more than ordinary care.

It may be said in general that there is little difference between the cost of erection and operation of chamber and contact plants. Some conditions favour the erection of chamber plants, but others are definitely in favour of contact plants. There is a distinct possibility that, with the further progress of engineering science and of our knowledge of catalysis, there will be a great increase in contact plants.

CONDITIONS FAVOURABLE TO CONTACT INSTALLATIONS

Briefly stated, the main conditions in favour of a site for contact acid manufacture are:

1. A demand for substantially pure acid, as, for example, for food stuffs, textiles, or tin-plates.
2. A demand for concentrated acid or oleum, as for example for dye stuffs, explosives, and synthetic chemicals.
3. The necessity for transporting the acid for considerable distances, where the shipment of a more concentrated acid can save freights.
4. The need for recovering acid from weak, cold, and wet gases such as those from sintering operations.
5. The possession of a cheap power and water supply.

Any one of the above considerations is sufficient to predispose the manufacture in favour of contact plants under normal conditions, unless the ore inherently possesses some disability which would make it not amenable to the purification treatment required in that process. Such a property would be rare.

CONTACT PLANT PURIFICATION SYSTEMS

The bugbear of the contact process is the poisoning of the catalyst or contact mass. The safe protection of the mass depends on the sufficiency of the purification system. A really adequate installation is therefore a fundamental necessity.

In all systems, the roaster gas is cooled, washed, filtered or otherwise treated for mist removal, and dried before passing to the contact chambers. Generally the cooling is preceded by a hot treatment for dust removal. This treatment varies from a simple flue or dust chamber settling of the gas to an elaborate electrostatic treatment. Dust chambers vary considerably in design and arrangement, from simple flue arrangements (Figure 1) to elaborate structures, as, for example, the Howard dust chamber (Figure 2). The sufficiency of the chamber depends on the type of roasting and the nature of the ore.

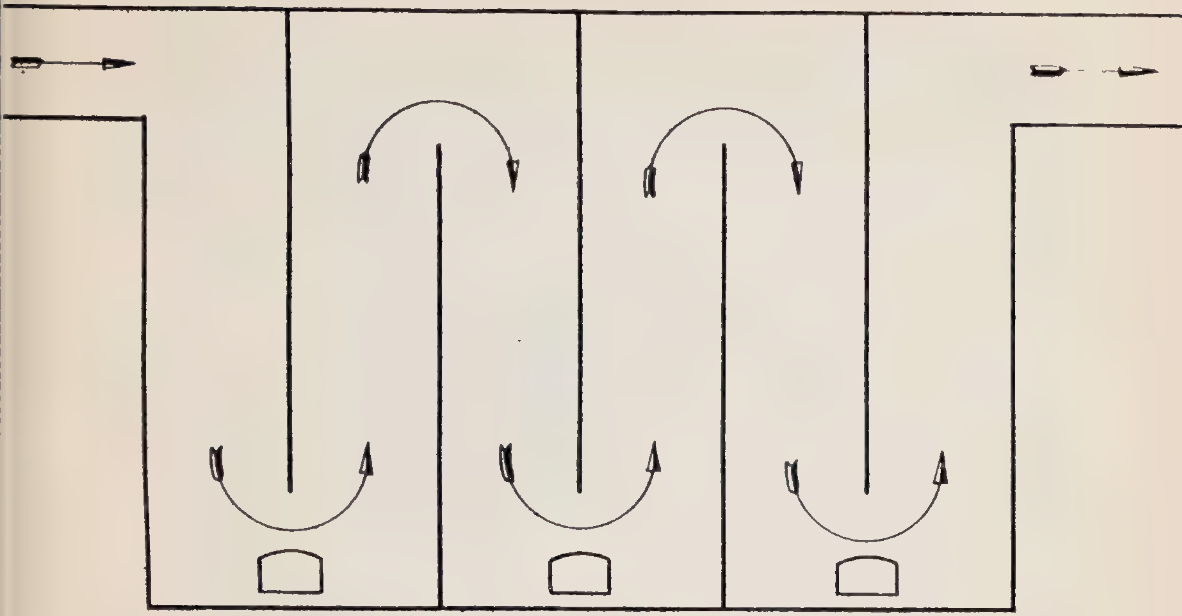


Figure 1.—Diagrammatic layout of simple static dust chamber.

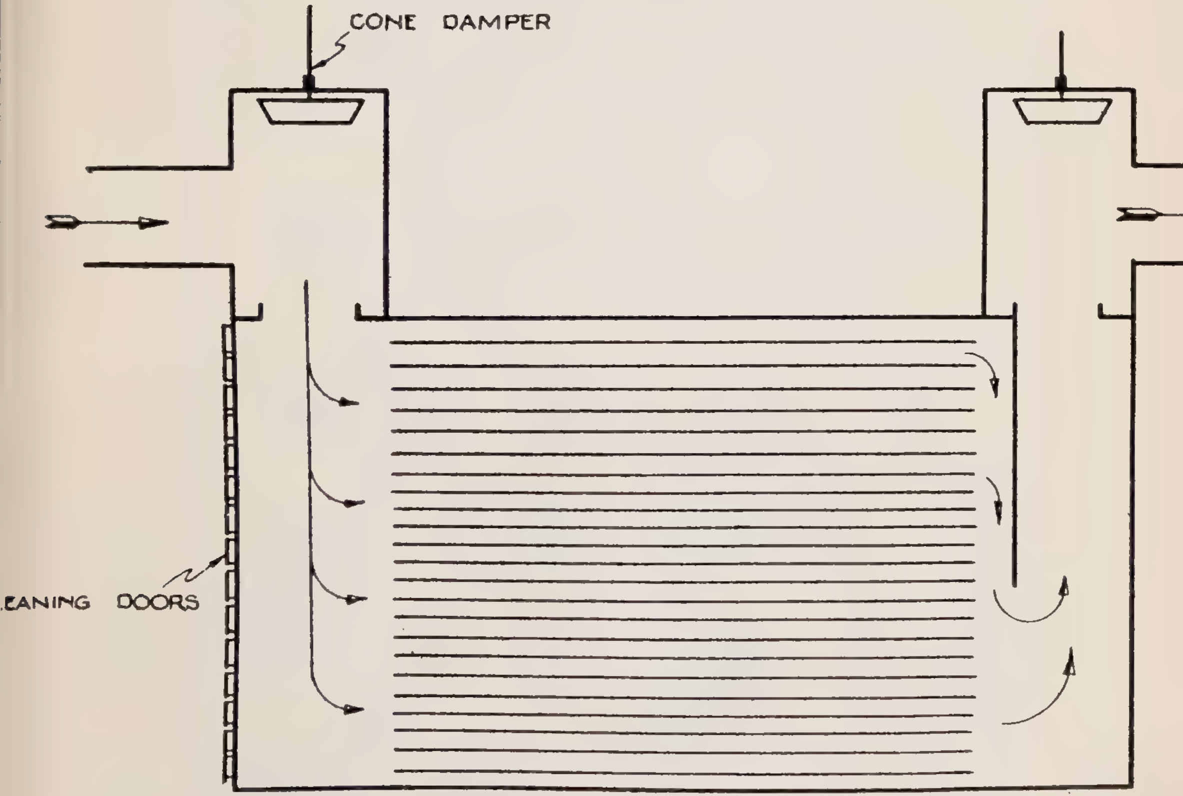
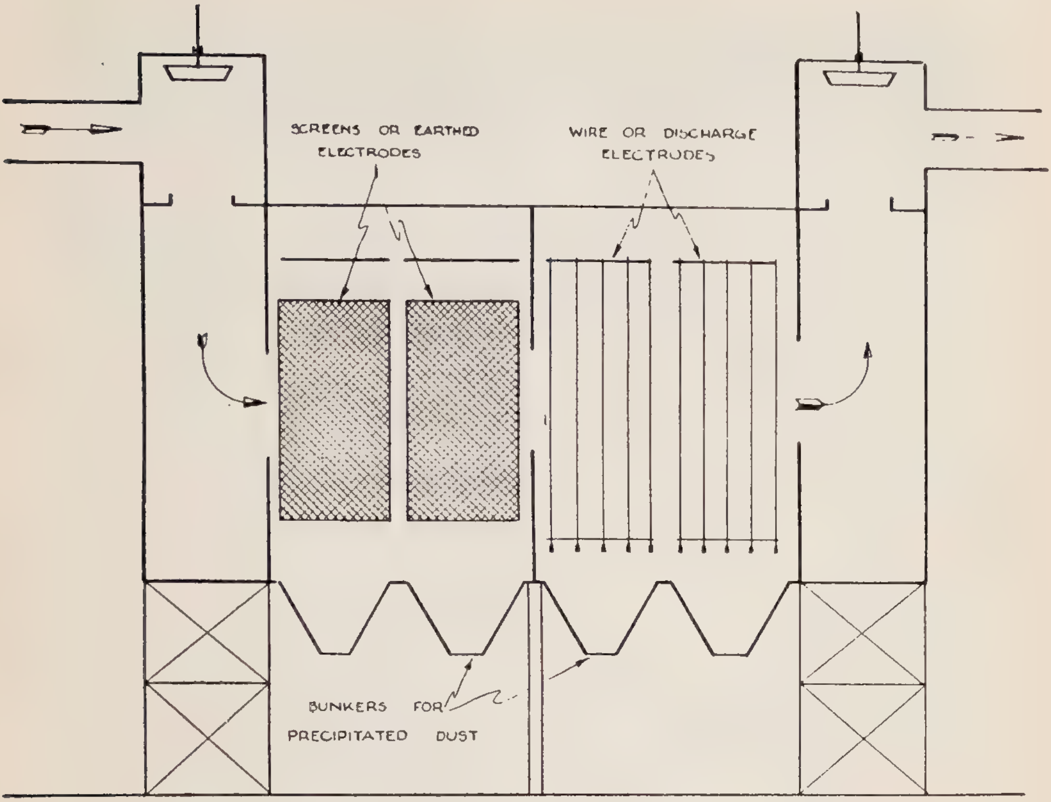


Figure 2.—Howard dust chamber, containing a large number of closely-spaced horizontal iron plates.

With slow roasting and hand rabbled furnaces like the Delplace roaster, little dust passes into the acid plant and a simple flue system suffices for the dust retention. If, on the other hand, the roasting operation is being forced, and particularly if appreciable lead is present in the blende, it is desirable to have more elaborate equipment. With mechanically rabbled furnaces, as efficient dust settling devices as possible should be employed, as much dust is invariably carried forward. There is no doubt that the amount of arsenic carried forward into the acid plant is sensibly (and out of proportion) borne by the fine dust leaving the roasters. In this connection it may be said that in a large contact plant operating without good dust settling arrangements with zinc concentrates which contained about 7 per cent lead, much lead passed into the scrubbing towers. It was found that whereas the acid liquors contained only .0005 per cent arsenic, the lead sludges collecting in the circulating tanks carried .016 per cent. Moreover, any 'stirring up' of these sludges invariably within a few minutes caused a drop in oxidation efficiency in the converters. Such conditions were therefore a constant source of danger to the plant, possible of satisfactory remedy only by improved dust removing facilities.

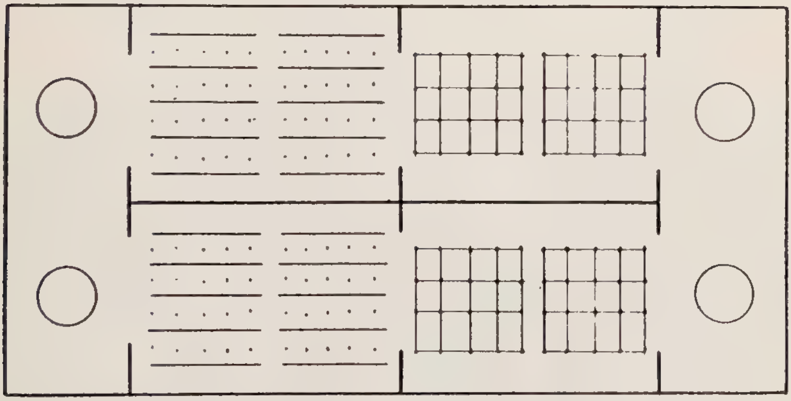
The most efficient type of dust removal which can operate under the conditions of a roasting installation is an electrostatic treater. Unless, however, the equipment is put in with very great care, the results will be disappointing. A very substantial structure is necessary for success, and the electrode area should be such that the velocity of the gas is not greater than one foot per second at operating temperatures of about 450°C. This is particularly important where the zinc ore contains appreciable lead, say, for example, 7 per cent. It is important, moreover, that the operating temperature should not exceed 500°C., as a rapid falling off in precipitating efficiency occurs above this point. Where the amount of material to be precipitated is large, and particularly in the presence of lead, an automatic rapping device for shaking the electrodes should be installed.

Adequately erected with due regard to these conditions, electrostatic depositors can be successfully used. Under any other conditions, as, for example, where ample space cannot


SCREENS OR EARTHED ELECTRODES
WIRE OR DISCHARGE ELECTRODES
BUNKERS FOR PRECIPITATED DUST

HALF SECTION SHOWING SCREENS HALF SECTION SHOWING WIRES

ELECTROSTATIC DEPOSITOR



HALF PLAN SHOWING SCREENS HALF PLAN SHOWING WIRES

Figure 3.

be given, erection is a mere waste of money, as precipitating efficiencies will be very low. Generally speaking, it is much more difficult to treat in this manner roaster gases from zinc blende than from pyrites, particularly if the blende contains more than 2 per cent lead.

An outline of an electrostatic treater is given in Figure 3.

A form of dust removal which is capable, with scientific development, of becoming of great utility and efficiency, is the 'cyclone' dust separator (Figure 4). In this case, the important condition is the attainment of the right velocity through the cyclone, so that the centrifugal effect will adequately separate the dust particles from the gas. Cyclones have been installed in numerous plants with fair success where the dust particles are not too fine. There is reason to believe that they can be substantially successful and will repay investigation by zinc manufacturers.

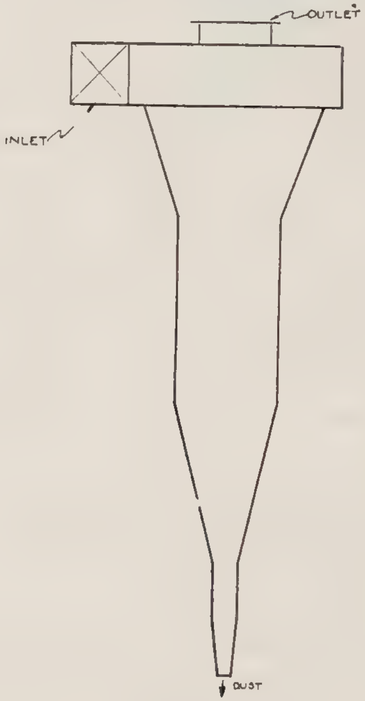


Figure 4.—Davidson cyclone.

The next stage common to contact processes where zinc blende is used is the cooling of the hot gas leaving the dust chamber. Two general methods are possible. The first method is to chill the gas by passage through cooling pipes or vessels. This method is safe, because the impure drip acid is continuously eliminated from the operating system. The cooler, however, requires considerable care in design if the gas passing into it is of very high temperature or imperfectly freed from dust. It is a false economy to attempt to construct the cooler of thin lead, and, particularly in the case of high inlet temperatures, the hot pipes or headers should be immersed in water. Two effective types are illustrated in Figures 5 and 6.

A much more thermally efficient type of cooler is an acid tower, such as the Glover tower. Moreover, under favourable conditions by its agency the drip acid can be worked up into a useful strength. Not all zinc blende gases can be safely worked up in this way. Where, however, the halide or arsenic contamination is not large, it is possible to work the plant with Glover tower cooling, followed by a weak acid washing. In such cases the weak acid condensed in the second or wash tower can be transferred to the Glover tower for concentration. Where, however, halide and arsenic contamination is heavy, these impurities will build up to dangerous limits before a useful acid concentration is reached.

No general rule can be given for the safe working limit of impurities in a Glover tower, as the governing factor is the nature of the ore.

After cooling it will be necessary to remove the remaining impurities in the gas. This must be done as completely as possible, and the existence of impurities in solid, liquid, and gaseous states is to be realized.

Experience indicates that the main impurities will be found in the so-called 'acid mist' which invariably separates when roaster gas is cooled. There is little doubt that the individual droplets of the mist carry with them finely divided dust particles and also, in an important manner, have dissolved gaseous impurities during the condensation process. There is evidence, however, to indicate that some gaseous impurities will, under certain conditions, escape being dissolved in the condensing mist and require special treatment. Nevertheless, it is apparent and true that the removal of acid mist effects a substantial portion of the gas purifying operation.

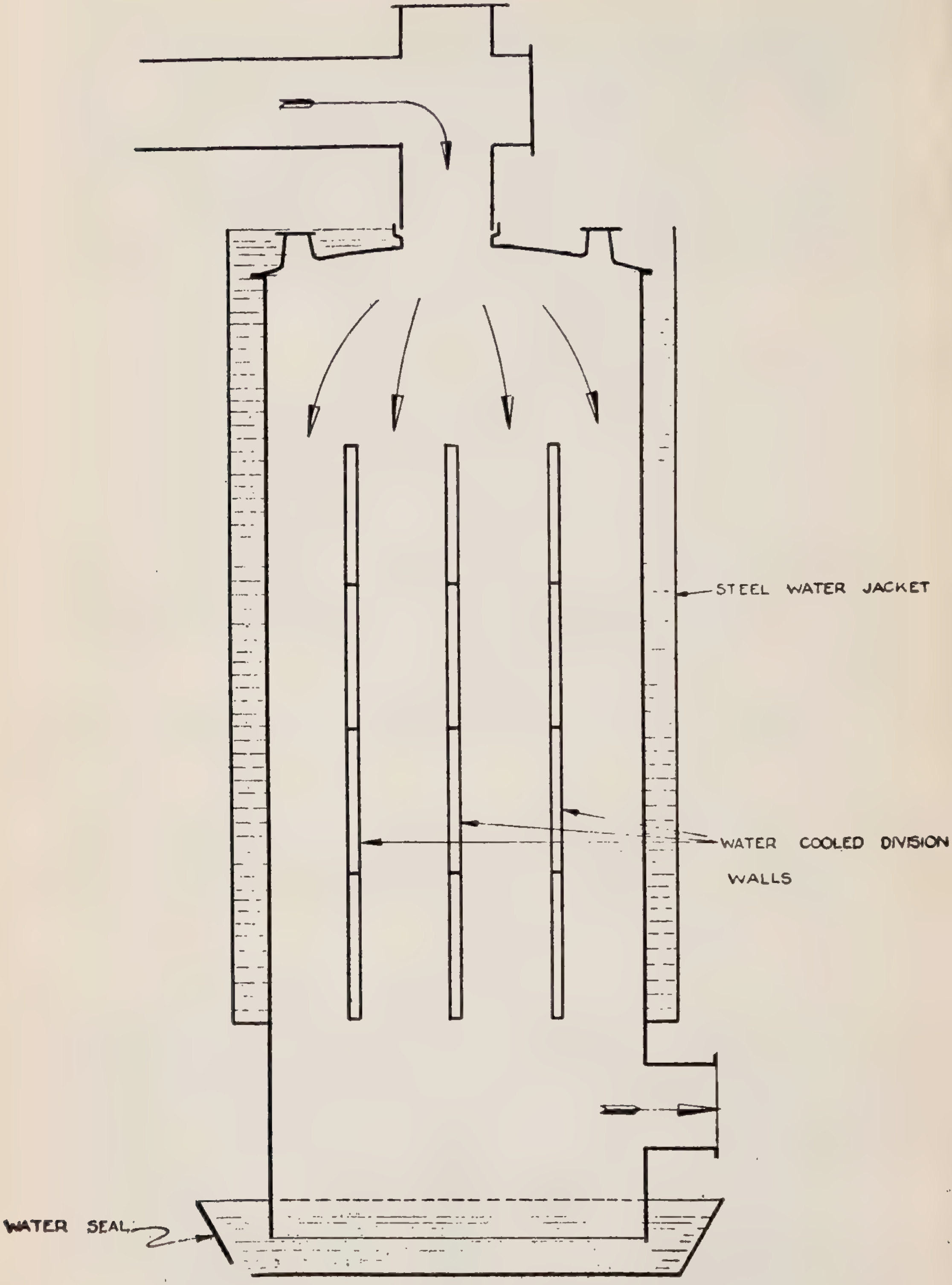


Figure 5.—Cast lead cooling tower, Tentelew process.

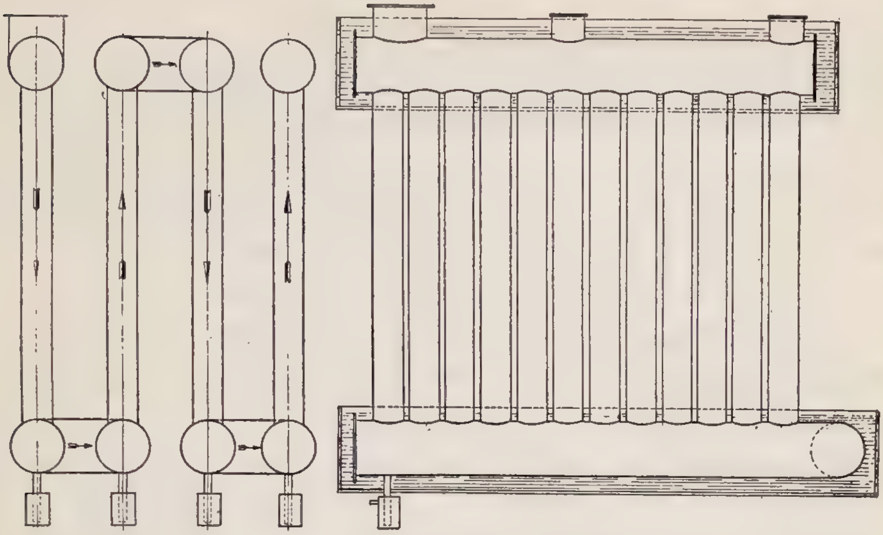


Figure 6.—Vertical gas cooler.

The mist particles are generally small and of a diameter of about 1.6×10^{-4} cm. The treatment therefore necessary to remove them must be rigorous. With roaster gases from zinc blendes, it is generally necessary to take great care over the purification process on account of the wide range of impurities normally present.

The methods employed after cooling the gas are: washing, filtration, and, in some cases, electrostatic treatment.

With blendes containing lead it is best to combine any filtration schemes with wet electrostatic treaters to avoid rapidly clogging up the filtering medium.

In the original Grillo installation, both washing and filtration were on an extensive scale. The outline of such an installation is indicated in the attached flow sheet, Figure 7.

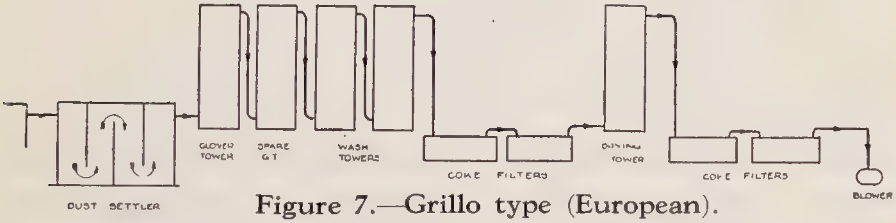


Figure 7.—Grillo type (European).

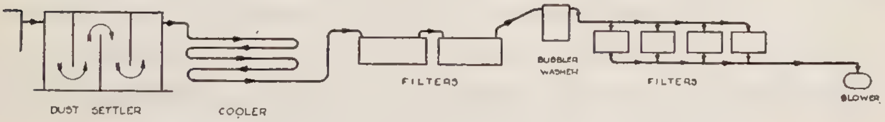


Figure 8.—Schroeder Grillo type (American).

Such plants were troublesome to operate where any heavy volatilization of leady products occurred in the roasters. With blendes—such as, for example, Australian concentrates—in many mechanically operated furnaces as much as 25 per cent or even 40 per cent of the lead present will pass into the acid plant and clog not only filters but also washing towers. Yet such plants are capable of commercial operation with many other blendes as far as ultimate purification is concerned. Simultaneously with the development of the Tower Grillo type plant in Europe, a predominantly filtration system of the same type was developed by the New Jersey Zinc Company, and worked with commercial success on many ores (See Figure 8). Again, however, with 'leady' ores, such as Australian concentrates, this system proved troublesome owing to blockage.

Zinc ores of 'leady' nature require means of mist removal which are not liable to clog up and are easy to clean. Electrostatic depositors are useful in this connection provided they are suitably designed. They should precede any closely packed tower and all filters, whose operation can then be continued for years without interruption.

The first contact plants operated by the National Smelting Company, of London, were plants of this nature (Figure 9).

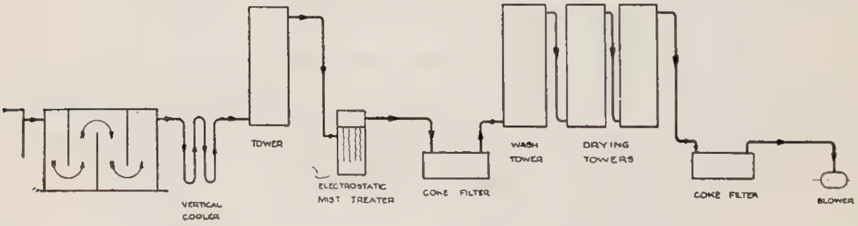


Figure 9.—National Smelting Company type for 'leady' zinc blendes.

In these plants very large lead volatilization occurred, and as much as 1,000 lb. per unit per day of lead sulphate was collected from the lead mains and electrostatic treaters. Without such protection, the coke-filled towers and filters of the plant would have been irretrievably blocked and plant operations interrupted.

The nature of the arrangements necessary in each case for using roaster gas from zinc blendes can only be determined after careful consideration and by technicians having experience in various types of plant.

The chief characteristics of the components of purification units can be briefly summarised under three heads:

(1) *Washing Devices*

Towers:

These need little description and can be built in any shape or size to suit the requirements of the plant and site. They are commonly circular or square in section, but in some plants the towers are rectangular in section and satisfactory service is given. The ratio of section to height is very variable also.

A most important feature in tower construction is the method of distribution of the liquor over the packing. This becomes particularly important with towers of large section, and it is always preferable to have easy inspection of the acid flow to ensure that the tower is kept well wetted. The method of packing the tower and the type of packing to be used vary considerably with the type of blende to be roasted. It is advisable, however, that the towers through which gas not completely freed from mist is being passed should be packed with open brickwork packing, particularly where much dust or lead is thrown off by the roasters. The remainder of the towers of the purification system can be packed in a variety of ways. Generally, the choice will lie between a coke packing and a special pot packing or even glass plates.

Special packings have the virtue of placing little impedence to the gas flow and displaying a maximum of wetted surface. Of all special packings, the glass packing is the most efficient and economical in space. With all special packings, very great care must be taken to ensure the whole of the top surface is wetted.

The tower filled with coke packing possesses two properties of great value. The first is that it constitutes an excellent filtration chamber, which cannot be said of the more open special fillings. The second is that it retains a large bulk of the washing liquor. This is of value in the case of drying towers, when any interruption of not more than an hour or so in the pumping arrangements can occur without allowing a serious amount of water to pass forward. Coke towers require less elaborate distribution arrangements than towers filled with special packings.

Bubbling Vessels:

While towers are by far the commonest washing devices there are some cases in which bubbling devices are used. These should, however, only be used where power is cheap, because they are effective mainly when opposing a considerable resistance to the gas stream. They are not suitable where the gas contains much solid suspension. Where, however, a multiple stage effect can be operated without fear of blockage, and where power is cheap, a very reliable form of purifier is obtained in this way (See Figures 10 and 11). Generally speaking, the many impurities present in blende gas have made such devices impracticable, although they have obtained considerable vogue in contact plants using pyrites roaster gas. It is necessary, where such bubblers are employed, to construct the plant extremely stoutly, and, in small units, to avoid collapse of the lead under the large sections created in drawing the gas through the heavy load of bubbling liquor.

Mechanical Washers:

Washers of this type have not been widely adopted on contact plants dealing with blende roaster gas, and it is not proved that they could meet the onerous conditions of the work, especially as final purifiers. The heavy sludges usually encountered, and the frequent occurrence of corroding impurities, such as mercury, would be especially deleterious to moving parts in 'ammonia washer' types, while simpler 'dasher' types are not rigorous enough for final washers.

Under conditions where mechanical washers are workable, they present a less costly treatment than bubbling towers, because, while retaining the multiple stage effect, they consume energy in throwing liquor through gas by efficient devices in place of forcing huge volumes of gas through the liquid by the less efficient help of fans. (See Figure 12).

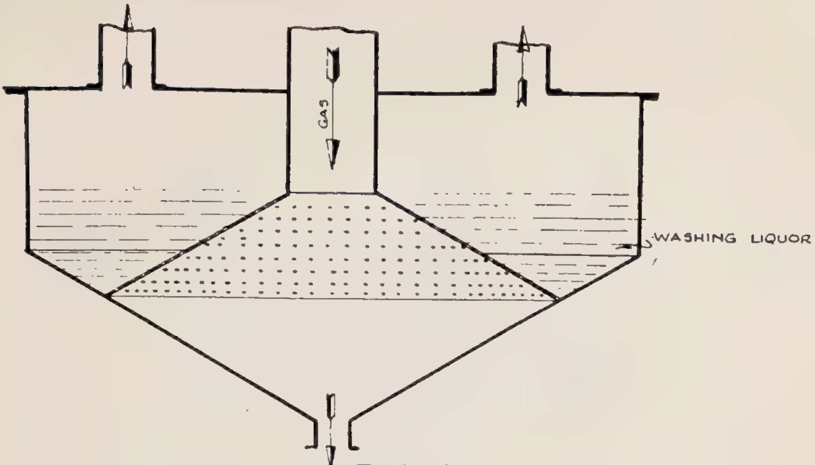


Figure 10.— Badische bubbler.

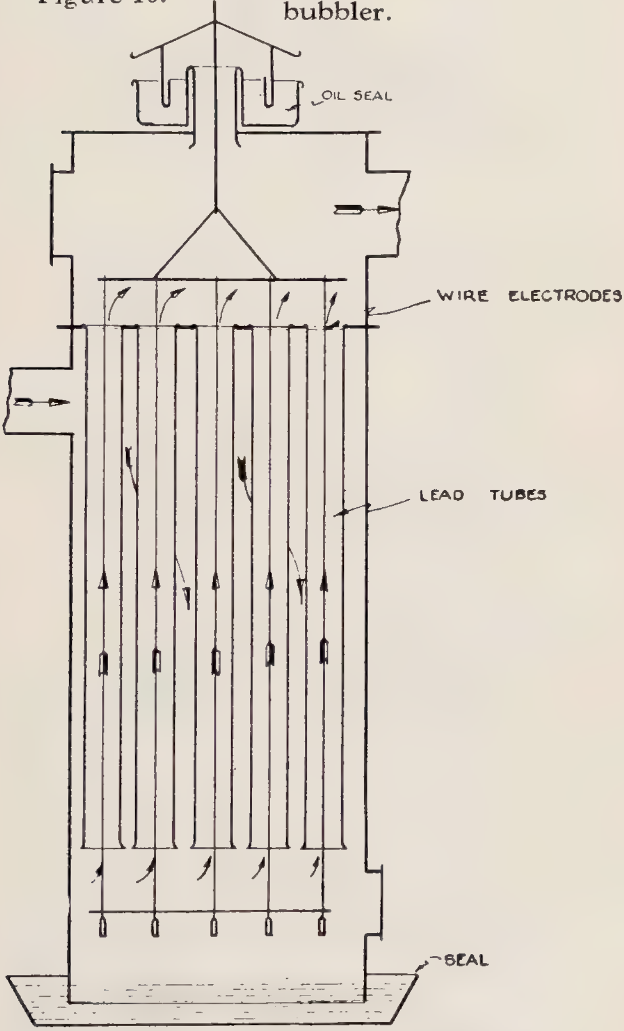


Figure 13.—Electrostatic mist treater.

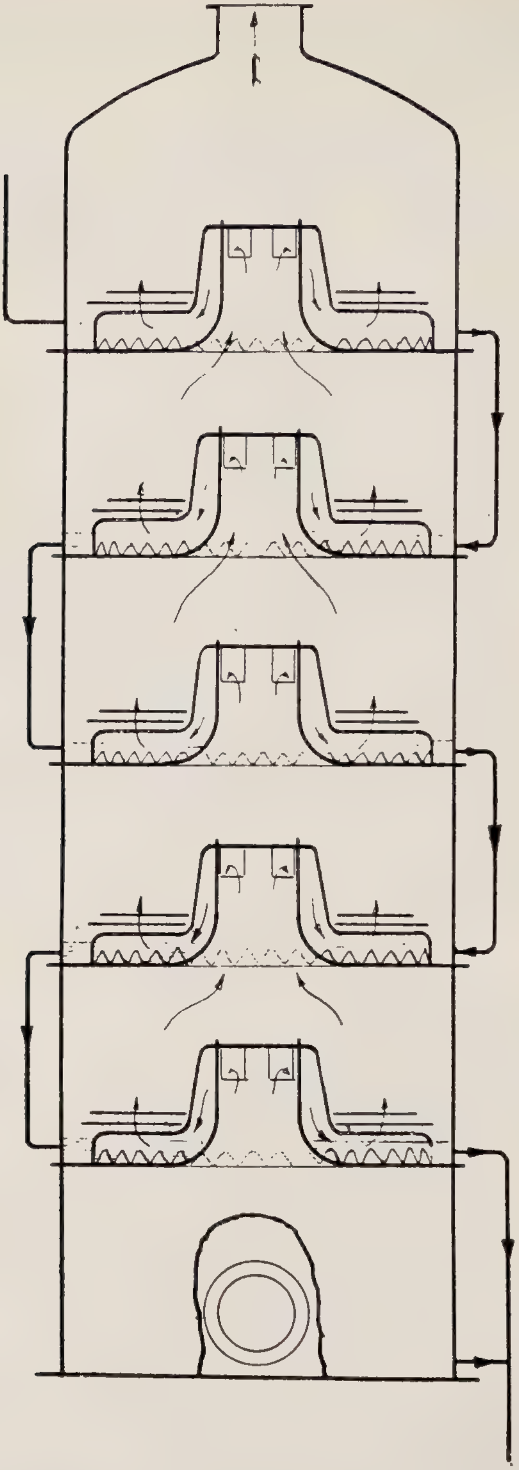


Figure 11.—Tentelew bubbler tower.

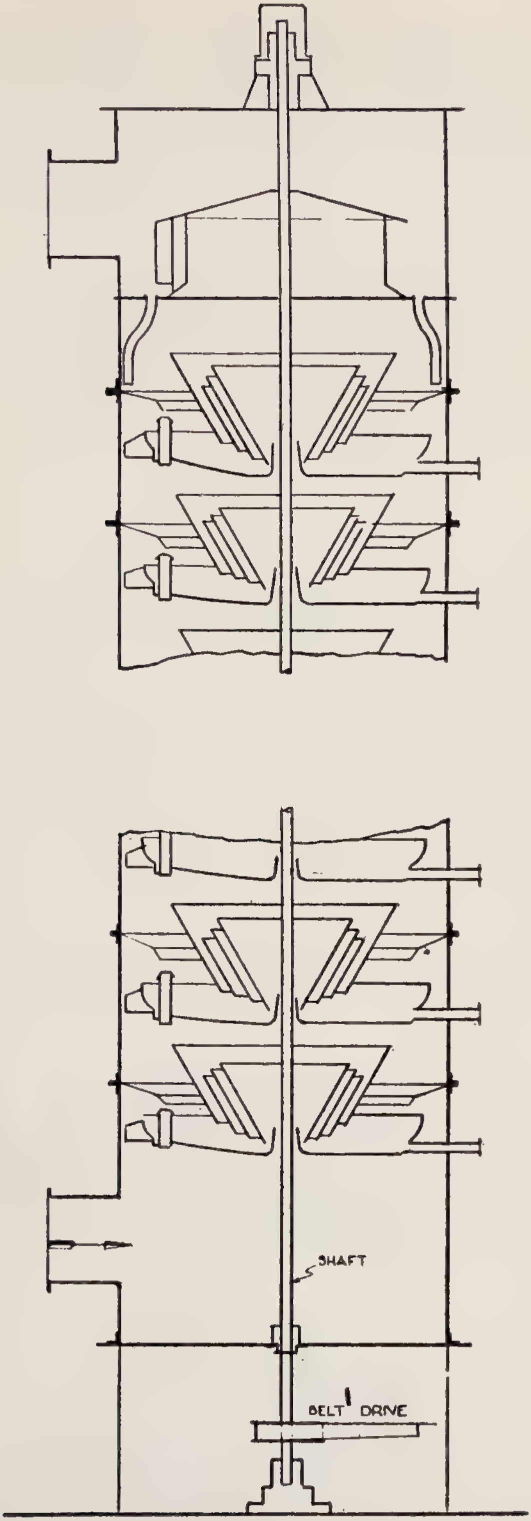


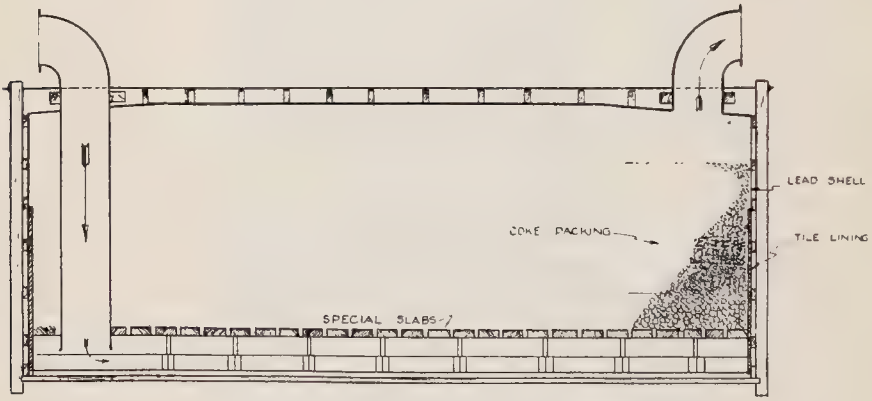
Figure 12.—Mechanical bubbler, Feld type.

Attempts to wash roaster gas efficiently with less power consumption by passage through a washer of large area with many perforations per square foot, have not been successful. It is necessary in all bubblers to have sufficient resistance to the gas flow to create a wire drawn effect on the gas as it passes through the perforations.

Similar attempts to throw out the mist particles by means of elaborate spraying devices, which would fill the chamber with an immense number of small droplets, have also failed. It seems necessary to hit the mist particles heavily with large droplets in order to bring about their deposition.

(2) *Filters*

Properly constructed filters (Figure 12a) are very efficient removers of mist and dust particles from roaster gas. They are not suitable, however, where much dust is encountered, because of their liability to clog up completely or channel when partially choked. They should always be placed after washing towers or other cleaning devices and never used, primarily, for dust removal. To be efficient, they must be of considerable dimensions, and if they are to fill a major portion of the cleaning operation should not pass more than 5 cubic feet of gas per minute per square foot of filtration area. Coke filters are the most commonly used but are, in most blende



COKE FILTER

FIG 12a

Figure 12a.—Coke filter.

plants, undersized. In some plants reliance is placed on asbestos fibre filters placed after the drying towers. With 'leady' blendes, they are not satisfactory, and their position at so late a stage of the purification system is not desirable where high oxidation efficiency is required of the converters. With simpler blendes and not too onerous requirements, they render good service and are easy to operate. At a sacrifice of some pressure loss they can be made to remove visible mist, but they are unable to remove any gaseous contamination.

(3) *Electrostatic Depositors*

An electric depositor is essentially the most efficient energy type for removing mist or solid particles from gas, because the energy consumed is directed only on the suspension and not on the whole mass of the gas or the washing liquor. This economy is now realised normally in practice. The process, moreover, does not necessarily involve a change in the velocity of the gas stream, and the separator offers no resistance, practically, to the flow of the gases. The method is to ionise the gases by passing them through high-tension uni-directional electric fields, which consist of a series of grids or pipes which are earthed and a series of wires which constitute the discharge electrodes. Under the influence of the electric fields the charged particles are attracted to the earthed electrodes and deposited.

Originally, failure was encountered on the application of this method because of the difficulty of maintaining the electrical insulation of the units. This particularly occurred at the first entry of the high-tension current into the treater chamber. The most successful method of overcoming this trouble has been to ventilate, and so keep clean, the insulator head by means of purified dry gas from the pressure side of the blower.

With the maintenance of this insulation in perfect condition, it has been found possible to remove mist from roaster gas with great efficiency. This method is particularly suitable where very dirty and foul gas is to be purified and is probably superior to all other methods in simplicity and economy of operation. It is particularly useful with gas from 'leady' blendes. A good type is illustrated in Figure 13.

GENERAL ORDER OF THE PURIFICATION PROCESS

The order of purification should generally be:

1. Dust removal.
2. Cooling.
3. Mist removal.
4. Removal of gaseous impurities.
5. Drying.

Removal of impurities after drying is only practicable under certain conditions.

Careful consideration of each case will be necessary before deciding what types of purifiers are to be used in each stage.

CONVERTER-HEAT-EXCHANGE SYSTEMS

The gas is invariably drawn from the purification system and forced through the converters by means of fans. Usually Roots type blowers have been used on account of their great reliability and low power consumption. The pulsations of the blower, however, often cause sufficient vibration in the gas to tear the adjoining lead work and there is reason to believe that a soft magnesium sulphate mass can be helped to crumble in the same way.

Centrifugal blowers, although generally less efficient energy units, are considerably cheaper in initial cost and can be installed in duplicate without increased expense above a single Roots type blower in some cases. The speed of rotation of the impeller in this type is sufficient to eliminate pulsations, and many new contact plants are now installing centrifugal or turbo blowers for their draught unit.

The purification system in a modern plant should be so efficient that no corrosion or accumulation of matter takes place at this point.

CONVERTER SYSTEM

The converter or contact chamber holds the catalytic material used for the oxidation of the sulphur dioxide of the roaster gas to sulphur trioxide. Its construction depends largely on the form of catalytic material to be used. Most contact plants employ some form of platinum catalyst. On account of the great cost of this metal and because the reaction appears to be largely promoted at the surface of the catalyst, it is the invariable practice to spread the platinum in the form of a very fine deposit over the surface of a 'support'. The type of support used today varies considerably, but the main classes are represented by calcined lumps of magnesium sulphate and asbestos fibre. The choice of the form to be employed depends on many circumstances. For many years it, however, has been the almost invariable practice of zinc blende roasters to use magnesium sulphate or Grillo masses. One of the main reasons for this lay in the ease of recovery of the platinum in the event of the mass being fouled or poisoned. Whereas, in the case of platinized asbestos, recuperation or recovery of the platinum from the fibre presented considerable difficulties owing to the physical properties of the asbestos, the magnesium sulphate could be surface-treated with dilute *aqua regia* or dissolved out completely in case of need.

This property was of very great value in the early days of contact plants, when purification processes were not well understood. They have less weight today. The more important properties of the two types can now be stated to be: in the case of magnesium sulphate, firstly its stability to heat without pulverizing, which far exceeds that of ordinary asbestos fibre; secondly its weight and bulk, which provide a large heat reservoir and admits prolonged stoppages of the process or marked irregularities in the sulphur content of the gas without undue heat variation; thirdly, the ease with which it can be filled into contact chambers of simple design; and fourthly, its amenability to treatment if fouled: while, on the other hand, asbestos suffers by comparison in these respects, and particularly requires much more complicated converter vessels to carry it without crushing into impermeable pads, it nevertheless presents a superior amount of surface to the gas and is generally more resistant to fouling than magnesium sulphate masses.

These properties are considered when determining the type of contact chamber to be erected. In this connection, also, it is necessary to determine to what degree of oxidation efficiency the process is to be worked. Many factors will influence this. In populous or highly agriculturalized areas, it is necessary to oxidize and absorb as completely as possible all the sulphur fumes. In other areas less complete absorption can be tolerated. In such cases as the latter it is possible to effect substantial economies in construction by making use of the property of platinum to convert or oxidize greatly increased amounts of sulphur dioxide with a small decrease in the efficiency or completeness of the oxidation. For example, it has been claimed that, whereas a given amount of platinum mass will convert, say, 100 parts of sulphur dioxide to sulphur trioxide almost quantitatively at 400°C., its progressive efficiency with rise in temperature is: 90 per cent at 500°C., and 80 per cent at 530°C.; but at 500°C., 18 times as much sulphur dioxide is converted as at 400°C., and at 530°C. the conditions for greater output are still more favourable.

Under these conditions the most suitable mass to employ is a magnesium sulphate type which will not disintegrate at the higher temperatures. This type of mass, indeed, seems fairly stable at 550°C.

The choice of a mass is a more open question at lower temperatures, where high efficiencies are required, and many technicians would favour asbestos fibre.

With platinum at a high and uncertain price, it becomes important to economize on the quantity employed. There is no doubt that substantial reduction can be effected in single-stage converters (See Figure 14), but the possible limit is affected by the influence of temperature. Further economies can be realised, therefore, by carrying out the conversion in two stages and making use of the higher velocity of the reaction

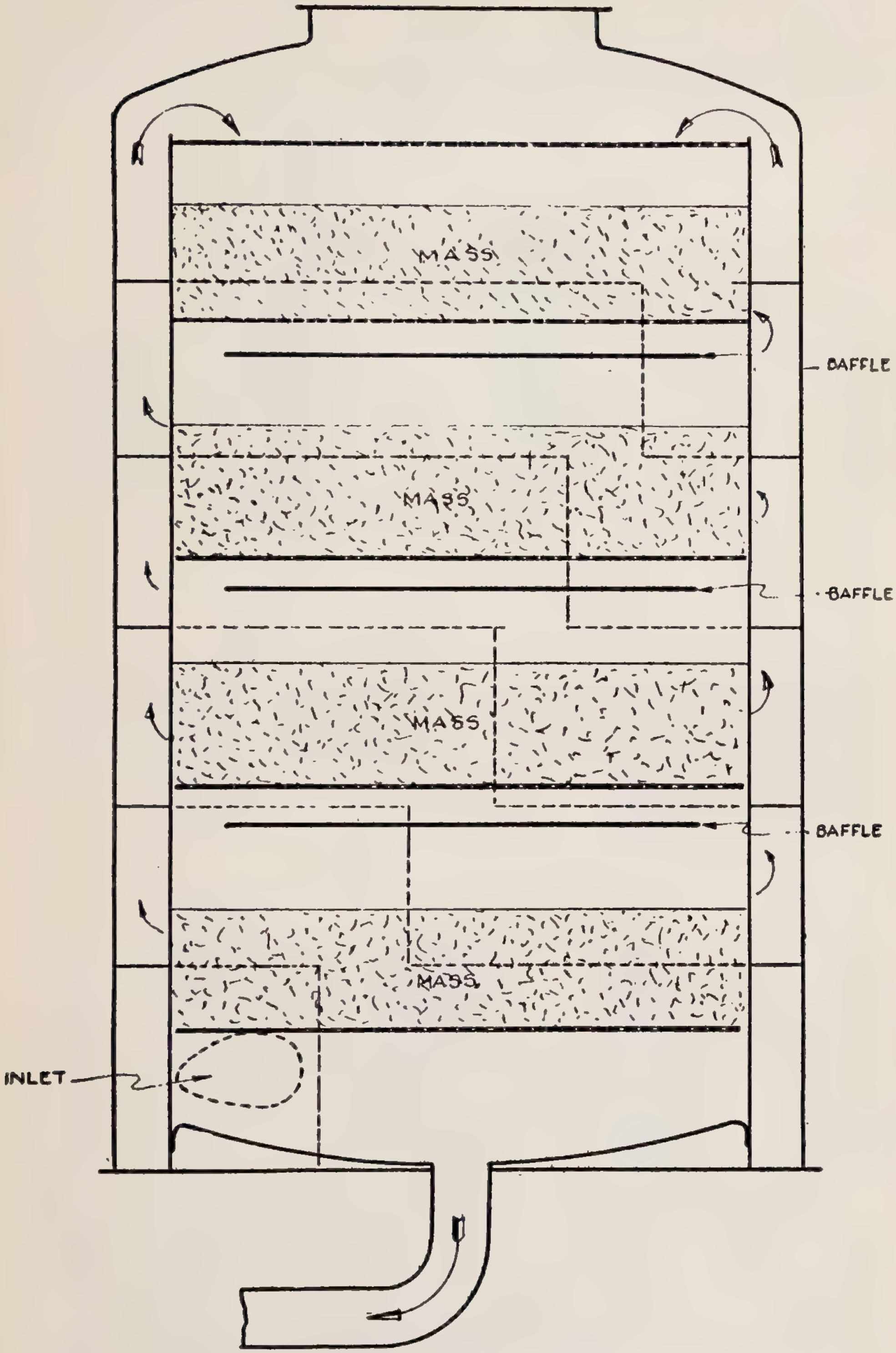


Figure 14.—Grillo converter. Magnesium-sulphate-type mass.

in the first and hotter stage. It is necessary to cool the gas leaving the first stage before passing through the second portion of the mass (See Figure 15). In such cases the superior heat resisting properties and simple chamber requirements of the magnesium sulphate mass may be used in the first and hotter mass, where most of the oxidation is effected, and the better surface of the asbestos in the second mass is valuable to complete the reaction at lower temperatures.

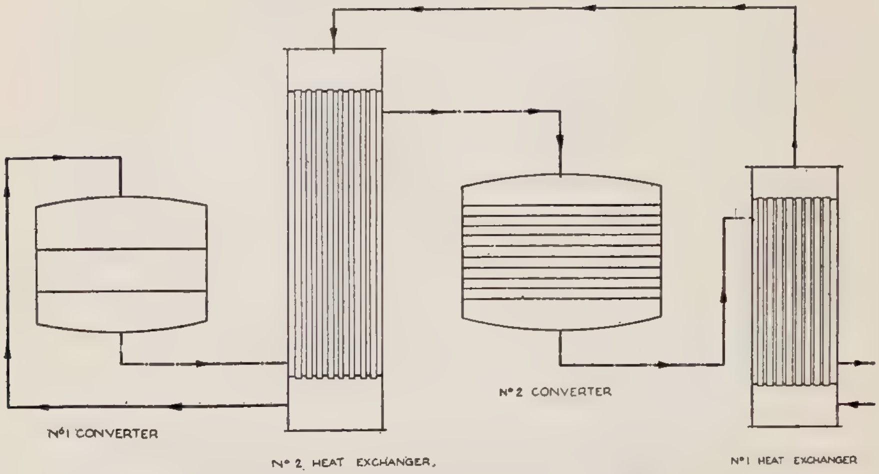


Figure 15.—Double converter type.

HEAT EXCHANGERS

In all modern plants, the heat produced by the oxidation of the sulphur dioxide to sulphur trioxide is utilized to pre-heat the cold purified gas passing from the fans sufficiently to allow a steady maintenance of the optimum temperature of the catalyst, which will vary from 450°C. to 530°C. or higher according to the type of converter.

It is possible to make a heat regenerative converter system for a gas containing 4 per cent sulphur dioxide, and plants regularly working under such conditions are in operation on blende roaster gas. It is necessary to maintain a high degree of gas purity to effect this result, and care must be taken to ensure complete dryness or heavy corrosion will be experienced in the heat exchangers.

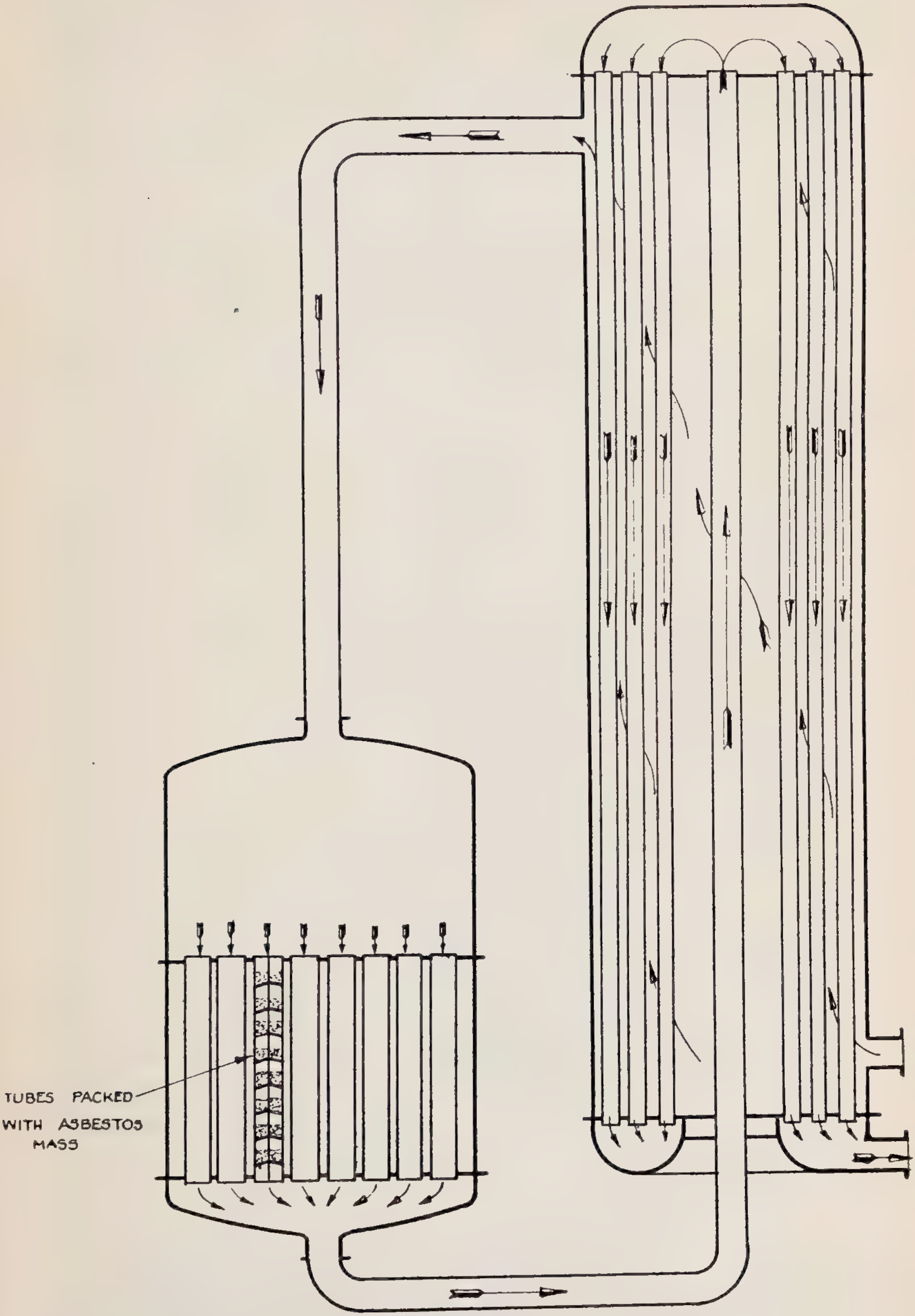


Figure 14a.—Tentelew converter and heat exchanger. Asbestos-type mass.

Given such conditions, it is possible to provide adequate heat exchange apparatus. It is necessary to allow, in the design of the heat exchangers, for rapid gas flow in order to attain sufficient heat transfer, and proper provision for heat expansion must not be overlooked (See Figure 16).

In many metallurgical operations it is difficult to obtain a gas containing as much as 4 per cent SO_2. In such cases it will be necessary to pre-heat the gas before it enters the converters. The heat exchangers must then be supplemented by externally fired pre-heaters. The supplementary heat required is that equivalent to the shortage of sulphur in the gas plus the increased radiation loss due to the higher temperature needed at the inlet of the converter. With properly designed equipment, the amount of fuel required, even for a gas containing between two and three per cent sulphur dioxide, at the converter should not be excessive, and, in a case operating at present on sinter gas produced from a Dwight Lloyd sintering plant operating with a pre-roasted ore containing 9 per cent sulphur, the amount of fuel is only about 15 per cent of the weight of monohydrate sulphuric acid produced. This figure is obtained on a plant designed for other purposes and could be improved.

Wherever constant use is to be made of externally fired pre-heaters, special care should be taken in their design. It is not advisable under such circumstances to employ highly efficient multi-tubular steel vessels, because, while such equipment can be used with fuel economy in starting up operations, the constant heat during continued use and the great care necessary to avoid overheat generally put such devices beyond practical working conditions and lead to serious burns-out. On the other hand, the massive cast-iron-pipe heaters common on many contact plants are thermally very inefficient and very costly to erect.

The advantage of robustness which is a feature of such types can be retained, and very material economies made in operating and erection costs, by putting many more pipes in the brick setting and so arranging them that the pipes themselves constitute baffles to the flow of the fire gas. It will be

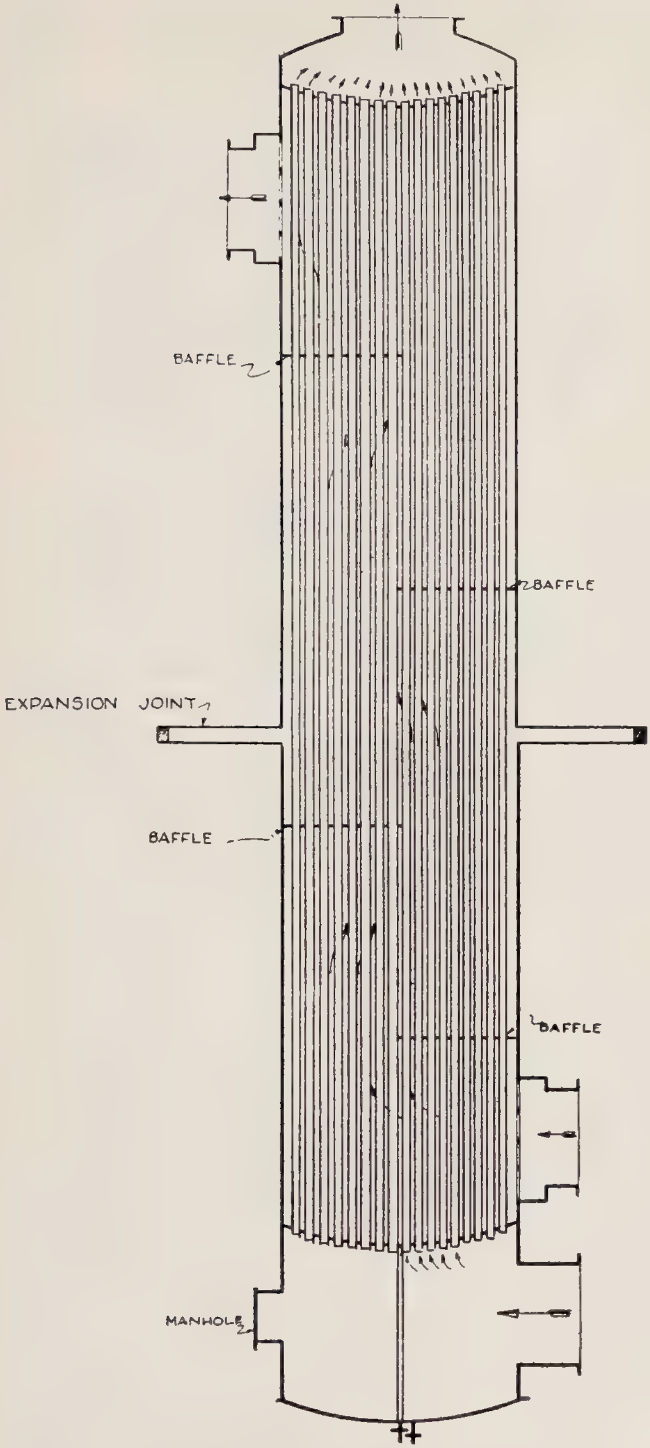


Figure 16.—Heat exchanger. The National Smelting Company type.

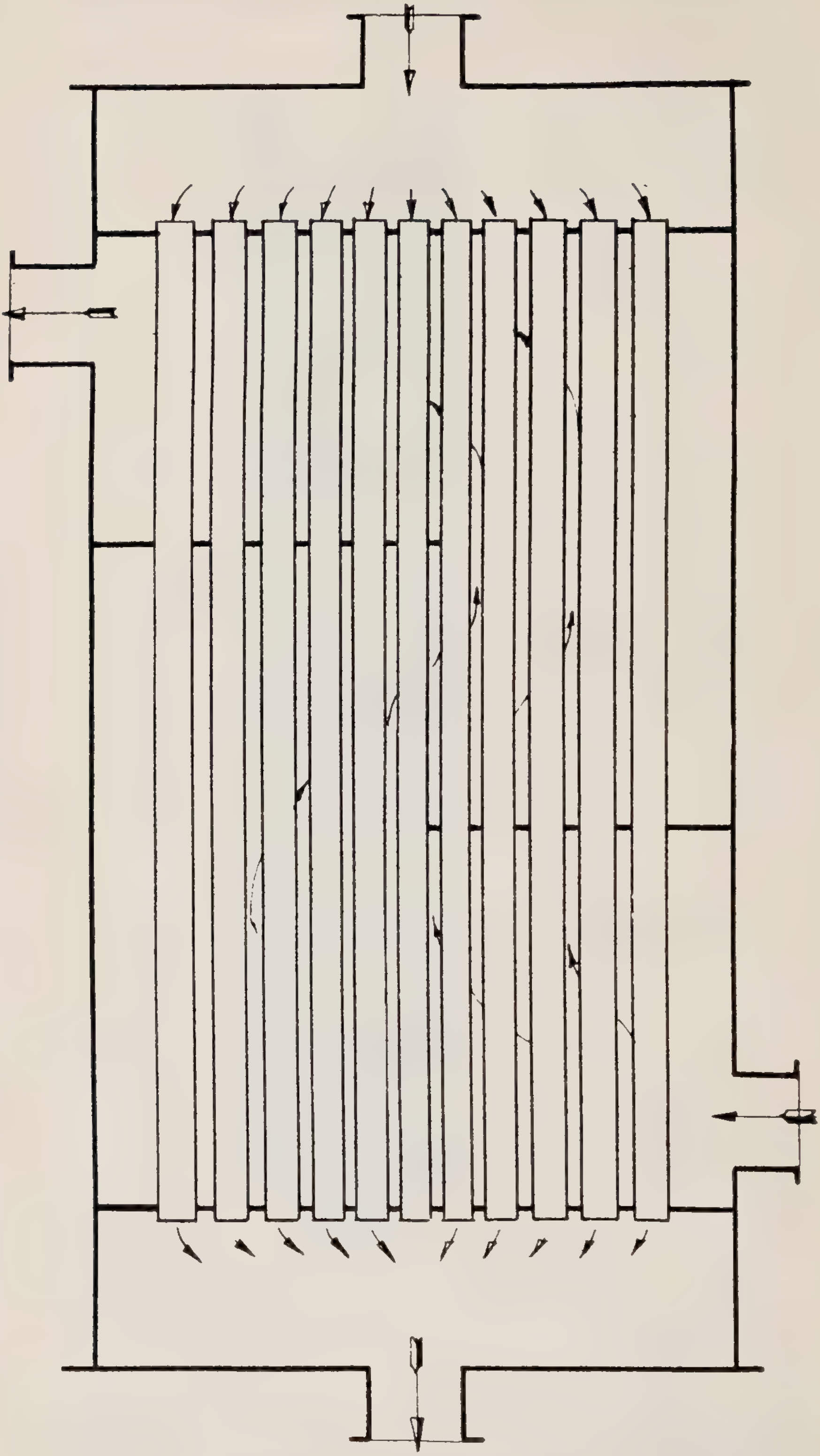


Figure 16a.—Heat exchanger.

found possible to work with appreciably cooler fires in such an arrangement and reduce the burning-out of pipes to a very small amount.

The gas leaving the converter heat exchange system is passed to an absorption system where it is completely stripped from sulphur trioxide, which, by its absorption in strong sulphuric acid and subsequent dilution with water, is made into sulphuric acid of any strength. Climatic conditions will determine whether it is necessary to cool the gas entering the absorption system, but, with blende roaster gas and a good heat exchange system, sulphur trioxide coolers are often not necessary.

The only really satisfactory type of absorber for comparatively weak gases like blende roaster gas is the tower type, because any bubbling system imposes too much resistance to the gas stream and thus consumes much energy. Many oleum plants have been fitted with simple bubbling vessels followed by absorption towers, but this is only desirable if oleum of great strength is required.

Unless every economy must be exerted to save even a small amount of power, the absorbers can be filled satisfactorily with lumps of quartz. Provided the plant is properly designed, the absorption of sulphur trioxide in the towers should be so complete as to render the gas leaving the absorber exits absolutely transparent.

POWER ECONOMY IN CONTACT PROCESSES

One of the most important items of cost in a contact acid plant is power. This is particularly true with gases from metallurgical operations, which are usually more dilute than those from pyrites or sulphur roasters whose main object is to provide suitable gas for acid making. For example, with a four per cent gas as compared with a seven per cent gas, the power costs are mainly in the ratio of seven to four. With blende roasting and with sintering processes, it is therefore essential to impose as little resistance to the gas as possible. This factor has been ignored in many designs. By omitting tightly packed small filters and tightly packed towers, and taking care of the size and arrangement of the connecting pipes, it was found possible at one of the plants of the National Smelting Company to work a relatively compact plant with a suction of 2½ in. water gauge and a pressure of 5½ in. water gauge. Under such conditions the power factor becomes exceedingly low and makes contact plants definitely competitive with chamber plants under any conditions.

The cost of breaking down the absorber tower acid of 98 per cent H_2SO_4 content to a strength of 78 per cent H_2SO_4 is often brought into discussions on the comparative merits of the chamber and contact systems. In practice, however, this breaking down cost, if carried out on the plant itself, is almost negligible.

CONTACT POISONS AND CONTACT MASSES

So hard were the troubles of earlier workers and plants on account of the poisoning of their contact masses that some special remarks in connection thereto are necessary.

Until the actual mechanism of catalytic processes is thoroughly understood it will always be difficult to understand contact poisoning.

Suffice it to state that, with an adequate gas purification system preceding it, a platinum contact mass will operate for many years without any serious alteration to its property of promoting oxidation. Whatever its method of operation, the platinum at the end of such a period is substantially the same as at the beginning.

A platinum mass is, however, very susceptible to the influence of impurities. Putting on one side the mechanical smothering of the mass, either by dust escaping from an insufficient purification system or by disintegration of the mass support, it may be said that poisoning can occur in several ways. Firstly, arsenic is an inhibitory agent. In the early days there was a tendency to consider that its influence was more potent than we now believe it to be. The slightest trace was supposedly fatal. This no doubt arose from assay reports of poisoned catalysts, wherein arsenic was always found to be present. Arsenic is an easily detectable element and can be picked up in mere traces. It, moreover, has great powers of dissemination owing to the facility with which it will form gaseous or easily volatile compounds, and owing to its amphoteric character. There is, therefore, possibility that arsenic should have been considered an indicator of the presence of other impurities in some cases of contact poisoning, rather than the active agent itself. Cases have indeed been noted where a poisoned mass contained relatively little arsenic compared with other masses working reasonably well and containing many times the arsenic contamination. There is no doubt, however, that arsenic can itself foul a mass, and whenever arsenic is present it should be eliminated to avoid definite risk of complete stoppage of the process and permanent ruin to the mass.

Chlorine is a very dangerous poison. In the absence of arsenic it will have marked, though probably transient, effects if its presence is not continuous. In the case of some contact plants in England operating on arsenic-free sulphur, the oxidation efficiency of the platinum mass was reduced to 30 per cent by the presence of salt in the sulphur due to sea-water wetting. On replacing the sulphur, however, the efficiency went back almost immediately to 96-97 per cent. The mechanism of such an inhibitory effect on the catalyst is not understood. The main danger from chlorine is, however, to be feared when it is accompanied by arsenic in the blende. Under such circumstances, purification difficulties may arise to a serious extent. Very regular running of the plant helps considerably in such circumstances, but there is the ever present danger of 'gushes' of hydrochloric acid being liberated by some accidental cause from washing liquors heavily loaded with that impurity, and carrying forward serious quantities of arsenic picked up from the various portions of the purification train, and passing forward in a very dangerous form which will lead to the permanent ruin of the mass. Many subtle cases of contact poisoning have been traced to such causes.

Fluorine is another of the halides which is often troublesome in acid making from zinc blendes. Apart from its injurious effect on the brickwork and packing of the towers of the plant, it forms compounds with silica which are often carried forward to the converter and slowly smother the catalyst. It is doubtful whether any serious action takes place in practice on the lead work of the installation due to fluorine compounds.

Mercury is another impurity encountered in some zinc blendes. This is a dangerous material from every point of view. Owing to its property of forming complex compounds, it is difficult to trace the manner of its transport through the plant. There are, however, undoubted cases of its presence in a gas which is optically free from mist and its subsequent appearance in filters and even in the converter itself. It is hardly to be doubted that the effect of this material on finely divided platinum will be permanently injurious. Apart from its influence on the catalyst, mercury has an unfortunate tendency to attack the lead work in patches and form areas which become disintegrated in a short period.

There are many other materials which can be stated to be injurious to the catalyst whenever platinum is used, but the foregoing are amongst the most important encountered in practice in blende roaster gas.

In all these cases the catalytic substance is platinum, and indeed, with very few exceptions, this is the only material in common use, as it is by far the most active agent known for the oxidation of sulphur dioxide to sulphur trioxide. Many substitutes have been tried, but the only ones in ordinary use are vanadium oxides and silver vanadate. They are, however, inferior in performance to platinum catalysts, and they are generally made to contain some platinum, either as a promoter or to complete the reaction. Vanadium masses are adversely affected by moisture in the gas and are very much less efficient oxidizing agents than platinum in dealing with gases weak in sulphur dioxide.

Other catalysts are under investigation which give considerably better performance than vanadium masses, and which have markedly greater resistance to impurities than platinum masses. Their composition is at present not divulged, but if the large-scale performance equals the indications of the bench trials, their influence on contact sulphuric acid methods will be profound.

To conclude, it may be said that the contact process is now sufficiently developed to enable the manufacture of sulphuric acid from roaster gas an economic possibility even if weak acid is required. It also will allow the operation of blende sintering processes without any serious loss of acid.

This has become a matter of great importance to zinc smelters working the distillation process, because sinter roast gives important economies in the retorts. Its adaptability to weak and wet gases renders the waste and nuisance from loss of metallurgical roaster fumes entirely unnecessary where sulphuric acid is marketable or can be used on the site. It also increases the economic range of distribution of the acid by 20 per cent. It is, nevertheless, necessary that complete cognisance of all the characteristics of the blende should be taken and the plant competently designed to meet the needs of the case before economic working can be obtained.

INTRODUCTORY REMARKS AND DISCUSSION

MR. ROBSON: I will endeavour to keep my introductory remarks within the ten minutes period. This paper is concerned primarily not with mining operations or mineral resources but with the recovery of sulphuric acid from the roasting operations of metallurgical processes where sulphide ores are treated. While hardly a primary concern of the metallurgical process itself, the recovery of the roaster gases which would otherwise escape to the air adds much to the amenities of life in the neighbourhood of the smelter or refinery.

It is not possible for me to cover the ground-work of this paper in a short summary as the subject matter of the paper is already very much condensed. For general details I must refer you to the paper itself. The manufacture of sulphuric acid has been developed along two distinct lines—one known as the 'chamber' process. In this process there is a consumption of nitre, in the oxidation of the sulphurous gases to sulphuric acid. The present paper does not deal with this old established and highly developed process, but with the 'contact' process, where the catalytic power of platinum or other substances is used to promote the oxidation.

The early work during the development of the contact process was fraught with many difficulties because the contact material or oxidizing agent was readily fouled and its oxidising powers destroyed by the many impurities which exist in the roaster gases and which have an inhibiting influence on those materials.

No reference could be made to the contact process of sulphuric acid manufacture as applied to zinc blende roasting without giving regard to the very valuable work of the metallurgists of the New Jersey Zinc Company in overcoming these difficulties.

The present paper deals only with the adaptation of the contact process to the zinc industry's needs and with regard to methods which have more recently developed. It may be said that the development of the contact process has occurred almost step by step with the development of engineering science and has accompanied the development of many other catalytic processes.

The conditions favourable to the contact process in preference to the chamber process have been summarized in the paper. Importantly among them is the demand for pure acid which is a normal product from 'contact' plants, inasmuch as it is necessary to completely purify the roaster gas in order to carry out the manufacture.

Another of the main assets of the contact process is that its product is a highly concentrated acid capable of economic transport over greater distances than the less concentrated acid produced by the chamber process.

One of the requirements of the contact process is cheap power and it may be said that where cheap power is available the manufacture of sulphuric acid by the contact process is essentially a cheap process.

A later development of some importance when zinc is manufactured by the distillation process, has been the production of a sintered roasted oxide. While in Canada, at the large works of the Consolidated Mining & Smelting Company at Trail, which we have recently visited, the electrolytic process has been developed largely, in many other places it has been found impossible to do this because an adequate supply of cheap power is not available. In such places the distillation method of manufacture of zinc is adopted and the use of sintered ore in the retorts has been helpful. In the Rigg method of sinter production, the ore has been pre-roasted.

The gas from this stage of the process is rich in sulphur dioxide. In the second or sintering stage of the process the gas is very weak and wet but can be used with the pre-roast gas to give a gas suitable for acid manufacture by the contact process where wetness and low temperature are of no consequence. Without such means in thickly populated industrial areas, particularly in countries like England where it would be impossible to send sulphurous gases continuously into the atmosphere, the contact process has been of great utility.

MR. G. J. V. CLARENCE (South Africa): How much platinum is used? We in South Africa are interested in platinum and the uses to which it is put.

MR. ROBSON: That is a question that demands a fairly wide answer. In many of the old contact processes, approximately one kilogram, or 2.2 pounds, of platinum were used in the production of ten tons of sulphuric acid. In many of the newer processes this figure has been considerably reduced and the amount of platinum which can be used for the oxidization of sulphurous gases is governed largely by the efficiency of the oxidation required in the process. To almost completely convert the sulphurous gases into sulphuric acid, and thus remove the nuisance which may be created by the fumes—say ninety-six per cent conversion—requires more platinum than to merely remove the major portion. It is impossible to give any definite figures, but it may be said that, with reasonably easy working and good efficiency, not much lower than 0.3 of a kilogram of platinum per ton of mono-hydrate produced can be used, although in some cases it has been claimed that the amount of platinum can be reduced even below that amount. Where lower oxidization efficiencies will suffice, substantially less platinum even than this figure is employed. If Mr. Clarence will make a calculation of the amount of sulphuric acid which is required to be made, using those factors, he will find, I am afraid, that the demand for platinum is not very great. Moreover, as in the recent processes the loss of platinum during the operation of manufacturing the acid is almost negligible, the replenishment amount is not very great.

CONTRIBUTED DISCUSSION

MR. W. H. DEBLOIS (Canada): Mr. Robson's paper is a comprehensive summary of the contact process for sulphuric acid as applied to waste sulphur gases from the smelting of zinc ores. Originally this process was developed for utilizing the gas from the burning of pyrite or similar ores, and the design of the burners was governed by the requirements of the acid plant. When, however, the question of utilizing sulphur gases from the smelting of sulphide ores arose, the problem was reversed, and the design of the acid plant necessarily had to be adapted to the conditions existing, for, in most cases, the smelting was the primary operation.

As emphasized in the paper, the purification of the gases is the main difficulty, and Mr. Robson's point that each problem should be studied by itself cannot be too strongly emphasized. Our experience on this Continent goes to prove that efficient filtration is of the utmost importance, and the various means employed are well summarized in the paper.

As regards the minimum concentration of SO_2, this resolves itself into a question of the available market and the price obtainable for acid. Unless the rail haul were comparatively short and the price higher than is usually obtained in this country or the United States, we would regard a 2 per cent gas as too low for economical operation. The size of the apparatus to handle such a large volume of inert gases would mean an almost prohibitive investment, apart from the cost of fuel for maintaining the necessary temperature for conversion, and other complications.

The data given correspond in the whole with our practice, although we would regard a temperature of 450°C. entering the contact chambers as too high for the best conversion. Most plants endeavour to operate at 360°C. to 400°C.

Mr. Robson also mentions that the asbestos contact mass is liable to disintegrate at the usual temperatures employed. If the proper grade of Canadian asbestos is used, however, little trouble will be experienced in this respect.

In comparing the contact with the chamber process for treating by-product gases, one of the principal advantages of the former is the fact that it can handle a variable gas with little or no loss in efficiency. The contrary is true of the chamber process, in which a steady gas is necessary if an excessive nitre consumption is to be avoided.

In conclusion, we welcome Mr. Robson's paper as an important contribution to the literature on the subject, and as an illustration that England is well to the front in the modern development of acid manufacture.

MR. ROBSON: I beg to thank Mr. W. H. DeBlois for his kind remarks and valuable comments. There is some little misunderstanding regarding the temperature of 450°C. to which reference has been made. This is probably due to a difference in the method of control of the converters between different operators. The temperature of 450°C. in this case is not the inlet temperature but the optimum maximum temperature recorded within the mass chamber itself. In many cases, to attain this temperature an average inlet of between 300°C. and 320°C. only is required when the gas contains about 4.5 per cent sulphur dioxide.

PROCEEDINGS. PART V

NON-FERROUS METALLURGY

PERSONAL INDEX

PAGE

Clarence, G. J. V., disc., Contact H_2SO_4 from Blende Gases.......... 97

Coleman, A. P., disc., Precious Metals in Sudbury Ores...............45, 46

DAVIS, CARL R., joint-author, paper, *Notes on the Operation of the Reduction Plant at West Springs, Ltd*.................................. 47-63

Dawson, J., disc., Precious Metals in Sudbury Ores..................41, 46

DeBlois, W. H., disc., Contact H_2SO_4 from Blende Gases.............. 98

EWING, S. E. T., joint-author, paper, *Notes on the Operation of the Reduction Plant at West Springs, Ltd*.................................. 47-63

Gibson, Thos. W., disc., Precious Metals in Sudbury Ores............. 42

Henderson, J. A. L., disc., Precious Metals in Sudbury Ores........... 45

JOHNSON, C., joint-author, paper, *Precious Metals in the Sudbury Ores and their Recovery*.. 35-41

Kitson, Sir Albert E., disc., Precious Metals in Sudbury Ores........... 44

LANGER, C., joint-author, paper, *Precious Metals in the Sudbury Ores and their Recovery*.. 35-41

ROBSON, STANLEY, paper, *The Contact Process for the Manufacture of Sulphuric Acid from Zinc Blende Roaster Gases*..................... 64-95

disc., Contact H_2SO_4 from Blende Gases........................95, 97, 99

Scott, O. N., disc., Precious Metals in Sudbury Ores.................. 45

Stanley, G. H., disc., Precious Metals in Sudbury Ores..............43, 45

STANLEY, ROBERT C., paper, *Nickel—Past and Present*................ 1-34

Wartenweiler, F., disc., Precious Metals in Sudbury Ores 44

WILLEY, J. L., joint-author, paper, *Notes on the Operation of the Reduction Plant at West Springs, Ltd*.................................. 47-63

GENERAL INDEX

PAGE

Argentan.................... 3
arsenic, a poison in contact process.................... 92

Badische bubbler............. 77
bronze, nickel..............19, 26, 31

Catalyzers, in contact process. 83, 94, 97
" nickel...........17, 29
chlorine, a poison in contact process.................... 93
coinage, nickel...............4, 14, 16
Contact Process for the Manufacture of Sulphuric Acid from Zinc Blende Roaster Gases, (Stanley Robson)............ 64-69
  conditions favourable to installations............. 66
  contact poisons and contact masses.................. 92-4
  converter — heat exchange systems................. 82-91
  cooling towers............. 70-3
  Davidson cyclone.......... 70
  electrostatic depositors..... 81
  filters..................... 80-1
  Howard dust chamber...... 67
  operating temperature...68, 98, 99
  power economy............ 91
  purification systems....... 66, 82
  washing devices............ 75-80
copper-nickel alloys.........17, 25, 29
corrosion-resistant nickel steel20, 26, 31

Davidson cyclone............. 70
dunite, platiniferous, at Onverwacht..................... 43

Electrostatic mist treater 77
electrum...................... 3

Feld-type bubbler 79
ferro-nickel alloys......8, 14, 20, 26, 31

PAGE

fluorine, a poison in contact process........................ 93

Gold, in Sudbury ores.........38, 42
" Coast, platinum in 44
Grillo converter 84
" installation, flow sheet 73

Heat-resisting nickel alloys ... .19, 25, 30
Howard dust chamber.......... 67

Invar.......................... 20
iridium, in Sudbury ores 38, 42

Lydenburg district, platinum in 43, 44

Magnesium, in malleable nickel. 5
malleable nickel...........5, 14, 19, 30
mercury, a poison in contact process....................... 94
metal blanc.................... 3
meteorites, nickel in............ 1
Middleberg district platinum reported in.................... 45
monel metal................14, 18, 29
Murray mine, discovered 7

National Smelting Co., contact plant of 74
" " " heat exchanger 88-9
Nickel—Past and Present, (Robert C. Stanley)................. 1-34
  bibliography.............. 31-34
  coinage 16
  commercial forms available . 23
  copper-nickel alloys.....17, 25, 29
  corrosion-resistant steel .20, 26, 31
  early history.............. 1
  ferro-nickel alloys .8, 14, 20, 26, 31
  heat-resisting and electrical alloys...............19, 25, 30

Nickel—Past and Present—con. PAGE
  malleable nickel.......5, 14, 19, 30
  market development....... 10
  monel metal............14, 18, 29
  nickel-aluminium alloys 27, 31
  nickel bronzes..........19, 26, 31
  nickel cast-iron.........21, 27, 31
  nickel catalyzers 17, 29
  nickel plating..............16, 28
  nickel-silver............15, 24, 28
  nickel steel ...8, 17, 24, 25, 28, 30
  present industrial uses...... 13
  price chart 20-21, 22-23
  production, by countries ... 8-9
  white gold 21, 27, 31
Notes on the Operation of the Reduction Plant at West Springs Ltd., (Carl R. Davis, J. L. Willey and S. E. T. Ewing).... 47-63
  costs...................... 48-55
  flow sheet............. 50-1, 52-3
  operation, notes on......... 55-6
  recovery.................. 62
  sorting and crushing 56-61
  tube milling plant.......... 58-61

ONVERWACHT, platinum in dunite of..........................43, 44

PAKTONG....................2, 3, 14
palladium, compound of, in S. African ore 43
  " in northwestern Ontario.............. 46
  " in Sudbury ores......38, 42
permalloy..................... 20
platinite...................... 20
platinum catalyzers, in contact process..........83, 94, 97
  " British Columbia...... 45
  " Gold Coast............ 44
  " northwestern Ontario... 46
  " Sierra Leone.......... 45
  " South Africa..........43, 44
  " Sudbury district.......38, 41

PAGE
poisons, in contact process....... 92

Precious Metals in the Sudbury Ores and their Recovery, (C. Langer and C. Johnson) 35-41
  bibliography................ 41
  International Nickel Co's process.................. 36
  Mond Nickel Co's process... 36
  precious-metal content of concentrate.............. 38
  recovery.................. 40
  refining process............ 38

Reduction Plant at West Springs, Ltd........................ 47-63
  see under *Notes on the Operation, etc.*
rhodium, in Sudbury ores.......38, 42
ruthenium, in Sudbury ores.....38, 42

SCHROEDER-Grillo installation, flow sheet................... 73
Sierra Leone, platinum in 45
silver, in Sudbury ores..........38, 42
South Africa, platinum in 43, 44
sperrylite, in S. African ore 43
Sudbury Ores, Precious Metals in.35-41
  see under *Precious Metals.*

TENTELEW bubbler tower....... 78
  " converter and heat exchanger 87
  " cooling tower........ 72
Transvaal, platinum in.........43, 44

VANADIUM, catalyst in contact process..................... 94

West Springs, Ltd., Operation of the Reduction Plant at 47-63
  see under *Notes on the Operation, etc.*
white copper.................. 2
white gold................21, 27, 31

TRENT UNIVERSITY
0 1164 0303145 7

TN5 .E6 1927 pt.5
Empire mining and metallurgical congress
... Proceedings

DATE	ISSUED TO 206774

206774